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ABSTRACT

This operations manual represents a continuation of operator training manuals developed for the United States Environmental Protection Agency (USEPA) in response to the technological advancements of wastewater treatment and the changing needs of the operations profession. It is intended to be used as a home-study course manual (using the concepts of self-paced instruction) or as a textbook for college and university courses. It contains chapters on: (1) the industrial plant operator; (2) activated sludge; (3) physical-chemical treatment; (4) instrumentation; (5) industrial waste monitoring; (6) industrial waste treatment processes; and (7) maintenance. Each chapter contains textual information, discussion and review questions, suggested answers, and an objective test. Included in the appendix are a final examination, tips on solving industrial waste arithmetic problems, a glossary of terms, and an index. (TW)

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A FIELD STUDY TRAINING PROGRAM

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SE 048 581

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INDUSTRIAL WASTE TREATMENT

A Field Study Training Program

prepared by

California State University, Sacramento
Department of Civil Engineering

in cooperation with the
California Water Pollution Control Association

****

Kenneth D. Kerri, Project Director
John Brady, Consultant and Co-Director

****

for the

Environmental Protection Agency
Office of Water Program Operations
Municipal Permits and Operations Division
First Edition, Technical Training Grant No. 5TT1-WP-16-03 (1970)
Second Edition, Grant No. T900690010

1987

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1. **Operation of Wastewater Treatment Plants,** 2 Volumes,
2. **Advanced Waste Treatment,**
3. **Treatment of Metal Wastestreams,**
4. **Pretreatment Facility Inspection,**
5. **Operation and Maintenance of Wastewater Collection Systems,** 2 Volumes,
6. **Water Treatment Plant Operation,** 2 Volumes,
7. **Small Water System Operation and Maintenance,** and
8. **Water Distribution System Operation and Maintenance.**

NOTICE

This manual is revised and updated before each printing based on comments from persons using the manual.

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PREFACE TO THE FIRST EDITION
of
INDUSTRIAL WASTE TREATMENT

This operations manual is a continuation of the evolution of operator training manuals developed for the US Environmental Protection Agency by California State University, Sacramento, and the California Water Pollution Control Association. As the technology of wastewater treatment advances and the training needs of the operations profession changes, we strive to keep our training programs current.

An analysis of the subject matter and the users of *OPERATION OF WASTEWATER TREATMENT PLANTS*, Volume III, revealed two distinct categories of operators using this manual to meet their training needs and to serve as an operations, maintenance and troubleshooting reference. Operators of industrial wastewater treatment plants need a training program that covers biological treatment processes as well as physical-chemical treatment processes. Operators of advanced wastewater treatment plants (tertiary plants) have similar needs, but with a different emphasis. One could argue that both groups could be served by a single manual or that two separate manuals could better serve the operations profession. If two separate manuals were to be prepared, how could the subject matter be appropriately divided and/or duplicated in each training program?

We have accepted this challenge and have prepared two new operator training programs using two new manuals, (1) *INDUSTRIAL WASTE TREATMENT*, and (2) *ADVANCED WASTE TREATMENT*. *INDUSTRIAL WASTE TREATMENT* covers the importance and responsibilities of an industrial wastewater treatment plant operator. Other topics include the activated sludge process, physical-chemical treatment, instrumentation, industrial waste monitoring, industrial waste treatment processes and maintenance. *ADVANCED WASTE TREATMENT* is a continuation of Volumes I and II of *OPERATION OF WASTEWATER TREATMENT PLANTS*. *ADVANCED WASTE TREATMENT* covers the topics of odor control, activated sludge, solids handling and disposal, solids removal from secondary effluents, phosphorus removal, nitrogen removal, wastewater reclamation and instrumentation. The decision to leave out the handling, treatment and disposal of industrial process solids from *INDUSTRIAL WASTE TREATMENT* was a difficult one. The industrial solids problem is serious and highly regulated. Since the processes used by many industries are highly specific and specialized, an attempt was not made to cover these processes. However, *ADVANCED WASTE TREATMENT* contains information on anaerobic and aerobic digestion, gravity thickening, centrifuges, chemical stabilization, thermal conditioning, wet oxidation, pressure filtration, belt filter presses, vacuum filtration, composting, incineration and land disposal.

Whenever California State University, Sacramento, reprints one of the operator training manuals, the material is updated in accordance with the comments and suggestions received from the operators enrolling in the courses which use the manual. While you are reading the material in this Manual, please make notes of questions and areas where you would improve the material. By sending your comments and suggestions to me, operators who use the manual in the future will benefit from your experience, knowledge and experience. Thanks.

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1987

PREFACE TO THE FIRST EDITION
OF
OPERATION OF WASTEWATER TREATMENT PLANTS

The purposes of this home study program are:

a. to develop qualified treatment plant operators;
b. to expand the abilities of existing operators, permitting better service to both their employers and the public; and
c. to prepare operators for *CERTIFICATION EXAMINATIONS*.[1]

To provide you with information needed to operate wastewater treatment plants as efficiently as possible, experienced plant operators prepared the material on treatment plant processes. Each chapter begins with an introduction and then discusses start up, daily operation, interpretation of lab results and possible approaches to solving operational problems. This order of topics was determined during the testing program on the basis of operators' comments indicating the information they needed most urgently. Additional chapters discuss maintenance, safety, sampling, laboratory procedures, hydraulics, records, analysis and presentation of data, and report writing.

Plant influents (raw wastewater) and the efficiencies of treatment processes vary from plant to plant and from location to location. The material contained in this program is presented to provide you with an understanding of the basic operational aspects of your plant and with information to help you analyze and solve operational problems. This information will help you operate your plant as efficiently as possible.

Wastewater treatment is a rapidly advancing field. To keep pace with scientific advances, the material in this program must be periodically revised and updated. This means that you, the operator, must recognize the need to be aware of new advances and the need for continuous training beyond this program.

Originally the concepts for this manual evolved from Mr. Larry Trumbull, 1967 Chairman of the Operator Training Committee of the California Water Pollution Control Association. Messrs. Bill Dendy and Kenneth Kerri, Project Directors, investigated possible means of financial support to develop and test the manual and prepared a successful application to the Federal Water Pollution Control Administration (5TT1-WP-16-03). The chapters were written, tested by pilot groups of operators and potential operators, reviewed by consultants and the Federal Water Quality Administration, and rewritten in accordance with the suggestions from these sources.

The project directors are indebted to the many operators and other persons who contributed to the manual. Every effort was made to acknowledge material from the many excellent references in the wastewater treatment field. Special thanks are due Messrs. John Brady and William Crooks who both contributed immensely to the manual. Mr. F.J. Ludzack, Chemist, National Training Center, Environmental Protection Agency, Water Quality Office, offered many technical improvements. A note of thanks is also due our typists, Miss Linda Smith, Mrs. Gloria Uri, Mrs. Daryl Rasmussen, Mrs. Vicki Sadlem, Mrs. Peggy Courtney, and Mrs. Pris Jernigan. Illustrations were drawn by Mr. Martin Garrity.

Following the first year of use by over 6500 operators and persons interested in operation, minor editing changes were necessary to correct typing errors and omissions and also to rewrite and expand questions and sections that could be clarified. Improvements suggested by operators using the manual were summarized and forwarded to a special Technical Advisory Task Force composed of operators familiar with the manual. This Task Force was formed as a subcommittee of the Water Pollution Control Federation's Personnel Advancement Committee and was chaired by Mr. Sam Warrington. We gratefully thank John Brady, Carlos Doyle, Otto Havens, Wilbur Holst, William Johnson, F.J. Ludzack and David Vandersommen for their efforts to improve our original version.

Kenneth D. Kerri
Bill Dendy

1973

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[1] *Certification examination. An examination administered by a state or professional association that operators take to indicate a level of professional competence. In most states the Chief Operator of a plant must be "certified" (successfully pass a certification examination), and in a few states certification is voluntary. Current trends indicate that certification of operators will be mandatory in all states in the near future.*

PREFACE TO THE SECOND EDITION
OF
OPERATION OF WASTEWATER TREATMENT PLANTS

During the 1970's many people decided that something must be done to control water pollution. The United States Congress passed the "Federal Water Pollution Control Act Amendments of 1972" (PL 92-500) and subsequent amendments. The objective of this Act is to restore and maintain the quality of the Nation's waters. In order to achieve this objective, the Act contains provisions for a financial grant program to assist municipalities with the planning, construction, start up and training of personnel in publicly-owned wastewater treatment plants. Grant funds have been used to build many new plants to date and many more plants will be built in the future. These plants are becoming more complex and are requiring operators with higher levels of knowledge and skills in order to insure that the plants produce a high quality effluent.

This manual, *OPERATION OF WASTEWATER TREATMENT PLANTS*, was used by over 40,000 persons interested in the operation of treatment plants during the 1970's. Every year when more manuals were printed, the manual was updated on the basis of comments and suggestions provided by persons using the manual. After six years of use by operators, the authors, the California Water Pollution Control Association, and the U.S. Environmental Protection Agency (EPA) decided that the contents of the manual should be reexamined, updated and revised. To accomplish this task, EPA provided the Foundation of California State University, Sacramento, with a grant to conduct the necessary studies, writing and field tests.

Recently the U.S. Environmental Protection Agency and the Association of Boards of Certification (ABC) have undertaken studies to document "need to know" tasks performed by wastewater treatment plant operators, skills required, alternative methods of training, training material needs and availability, and the development of instructional materials for certification examinations. Every effort has been made to incorporate the results of these studies in this Second Edition of *OPERATION OF WASTEWATER TREATMENT PLANTS*.

The project directors are indebted to the many operators and other persons who contributed to the Second Edition. Material from the many excellent references in the wastewater treatment field has been acknowledged wherever possible. Joe Bahnick, Ken Hay, Adelaide Lilly, Frank Lapensee, Jack Samson and Bob Rose, U.S. Environmental Protection Agency, served ably as resource persons, consultants and advisers. Special thanks are due our project consultants, Mike Mulbarger, Carl Nagel and Al Petrasek who provided technical advice. Our education reviewers were George Gardner and Larry Hannah. Christine Umeda and Marlene Itagaki administered the national field testing program. A note of thanks was well earned by our typists Charlene Arora, Elaine Saika and Gladys Kornweibel. Illustrations were drawn by Martin Garrity.

Kenneth D. Kerri
John Brady

1980

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USES OF THIS MANUAL

Originally this manual was developed to serve as a home-study course for operators in remote areas or persons unable to attend formal classes either due to shift work, personal reasons or the unavailability of suitable classes. This home-study training program used the concepts of self-paced instruction where you are your own instructor and work at your own speed. In order to certify that a person had successfully completed this program, an objective test was included at the end of each chapter and the training course became a correspondence or self-study type of program.

Once operators started using this manual for home study, they realized that it could serve effectively as a textbook in the classroom. Many colleges and universities have used the manual as a text in formal classes often taught by operators. In areas where colleges were not available or were unable to offer classes in the operation of wastewater treatment plants, operators and utility agencies joined together to offer their own courses using the manual.

Occasionally a utility agency has enrolled from three to over 300 of its operators in this training program. A manual is purchased for each operator. A senior operator or a group of operators are designated as instructors. These operators help answer questions when the persons in the training program have questions or need assistance. The instructors grade the objective tests at the end of each chapter, record scores and notify California State University, Sacramento, of the scores when a person successfully completes this program. This approach avoids the long wait while papers are being graded and returned by CSUS.

This manual was prepared to help operators run their treatment plants. Please feel free to use it in the manner which best fits your training needs and the needs of other operators. We will be happy to work with you to assist you in developing your training program. Please feel free to contact

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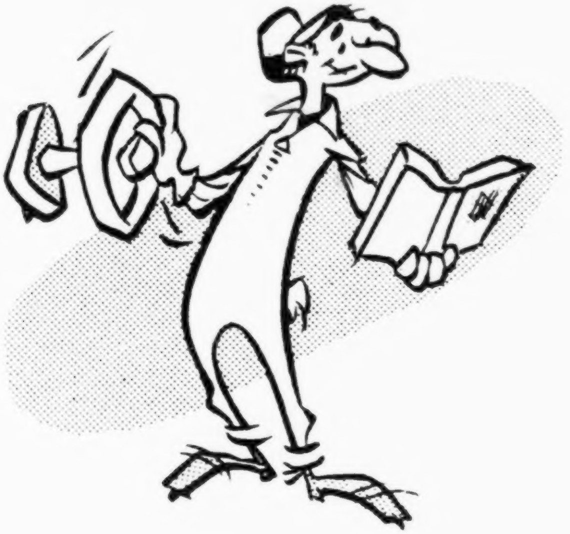
INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE

Procedures for reading the lessons and answering the questions are contained in this section.

To progress steadily through this program, you should establish a regular study schedule. For example, many operators in the past have set aside two hours during two evenings a week for study.

The study material is contained in seven chapters. Some chapters are longer and more difficult than others. For this reason, many of the chapters are divided into two or more lessons. The time required to complete a lesson will depend on your background and experience. Some people might require an hour to complete a lesson and some might require three hours; but that is perfectly all right. *THE IMPORTANT THING IS THAT YOU UNDERSTAND THE MATERIAL IN THE LESSON!*



Each lesson is arranged for you to read a short section, write the answers to the questions at the end of the section, check your answers against suggested answers; and then *YOU* decide if you understand the material sufficiently to continue or whether you should read the section again. You will find that this procedure is slower than reading a normal textbook, but you will remember much more when you have finished the lesson.

At the end of each chapter, you will find an "objective test." Mark your answers on the special answer sheet provided for each chapter. Some discussion and review questions are provided following each lesson in the later chapters. These questions review the important points you have covered in the lesson.

The objective test at the end of each lesson contains true or false, multiple-choice, fill-in-the-blank, or match-the-answers types of questions. The purposes of this exam are to review the chapter and to give experience in taking different types of exams. *MAIL TO THE PROGRAM DIRECTOR ONLY YOUR ANSWERS TO OBJECTIVE TESTS ON THE PROVIDED ANSWER SHEETS.*

After you have completed the last objective test, you will find a final examination. This exam is provided for you to review how well you remembered the material. You may wish to review the entire manual before you take the final exam. Some of the questions are essay-type questions which are used by some states for higher-level certification examinations. After you have completed the final examination, grade your own paper and determine the areas in which you might need additional review before your next examination.

You are your own teacher in this program. You could merely look up the suggested answers from the answer sheet or copy them from someone else, but you would not understand the material. Consequently, you would not be able to apply the material to the operation of your plant nor recall it during an examination for certification or a civil service position.

YOU WILL GET OUT OF THIS PROGRAM WHAT YOU PUT INTO IT.

SUMMARY OF PROCEDURE

A. OPERATOR (YOU)

1. Read what you are expected to learn in each chapter (from Chapter 2 on, the major topics are listed at the beginning of the chapter).
2. Read sections in lesson.
3. Write answers to questions at end of sections in your notebook. You should write the answers to the questions just like you would if these were questions on a test.
4. Check your answers with suggested answers.
5. Decide whether to reread section or to continue with the next section.
6. Write answers to discussion and review questions at the end of lessons in your notebook.
7. Mark answers to objective test on answer sheet.
8. Mail material to project director.

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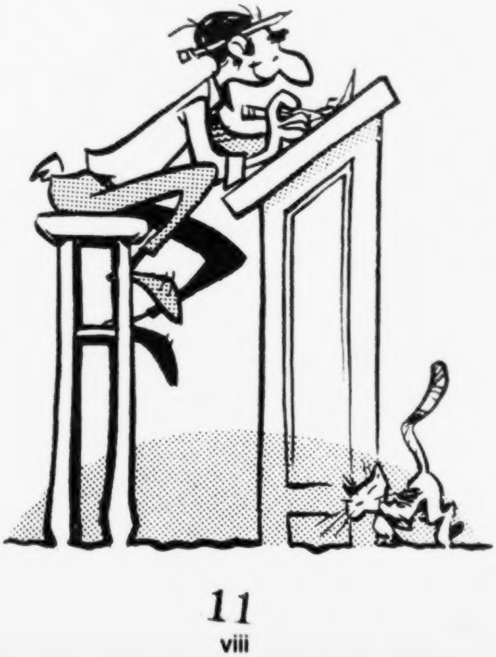
B. PROJECT DIRECTOR

1. Mails answer sheet for each chapter to operator.
2. Corrects tests, answers any questions, and returns results to operators.

C. ORDER OF WORKING LESSONS

To complete this program you will have to work all of the chapters. You may proceed in numerical order, or you may wish to work some lessons sooner.



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TECHNICAL CONSULTANTS

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Larry Trumbull

OPERATION OF WASTEWATER TREATMENT PLANTS
COURSE OUTLINE
VOLUME I, THIRD EDITION

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CHAPTER 1

THE INDUSTRIAL PLANT OPERATOR

by

Ken Kerri

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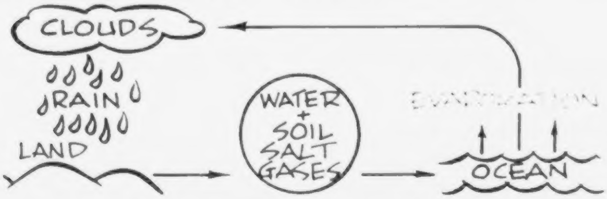
CHAPTER 1. THE INDUSTRIAL PLANT OPERATOR

This portion of Chapter 1 was prepared especially for the new or the potential industrial *WASTEWATER*[1] treatment plant operator. If you are an experienced operator, you may find some new viewpoints.

1.0 WHAT IS AN INDUSTRIAL PLANT OPERATOR?

Before modern society entered the scene, water was purified in a natural cycle as shown below:



Simplified natural purification cycle

But modern society and the intensive use of the water resource and the resulting water pollution could not wait for sun, wind, and time to accomplish the purification of soiled water; consequently, municipal and industrial treatment plants were built. Thus, nature was given an assist by a team consisting of designers, builders, and treatment plant operators. Designers and builders occupy the scene only for an interval, but operators go on forever. They are the final and essential link in maintaining and protecting the aquatic environment upon which all life depends.

1.01 What does an Industrial Plant Operator do?

Simply described, the operator keeps an industrial wastewater treatment plant working. Physically the operator turns valves, pushes switches, collects samples, lubricates equipment, reads gages and records data.

An operator may also maintain equipment and plant area by painting, weeding, gardening, repairing and replacing. Mentally an operator inspects records, observes conditions, makes calculations to determine that the plant is working effectively, and predicts necessary maintenance and facility needs to assure continued effective operation of the plant. The operator also has an obligation to explain to supervisors, management, civic bodies, and even the general public what the plant does, and most importantly, why the industry and its facilities are vital to the welfare of the community.

1.02 Who does the Industrial Plant Operator work for?

An operator's paycheck comes from the industry which employs the operator. As an operator you are responsible to your employer for maintaining an economically and efficiently operating facility. An even greater obligation rests with the operator because the great numbers of people who rely upon downstream water supplies are totally dependent upon the operator's competence and trustworthiness for their welfare. In the final analysis, the operator is really working for these vitally affected downstream water users.

1.03 Where does the Industrial Plant Operator work?

Obviously the operator works in an industrial treatment plant. But the different types and locations of treatment plants offer a wide range of working conditions. From the mountains to the sea, wherever people congregate into communities, industrial treatment plants will be found. From a unit process operator at a complex industrial facility to a one-person manager of a small pretreatment facility, you can select your own special place in industrial plant operation.

1.04 What pay can an Industrial Plant Operator expect?

In dollars? Prestige? Job satisfaction? Community service? In opportunities for advancement? By whatever scale you use, returns are what you make them. If you choose a large industry, the pay is good and advancement prospects are tops. Choose a small facility and pay may not be as good; but job satisfaction, freedom from time-clock hours, service, and prestige may well add up to outstanding personal achievement. Total reward depends on you.

The operator's duties

1.05 What does it take to be an Industrial Plant Operator?

Desire. First you must choose to enter this profession. You can do it with a grammar school, a high school, or a college education. While some jobs will always exist for manual labor, the real and expanding need is for *TRAINED OPERATORS.* New techniques, advanced equipment, and increasing instrumentation require a new breed of operator,

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[1] Wastewater. The used water and solids from an industry or a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

one who is willing to learn today, and gain tomorrow, for surely your industrial plant will move towards newer and more effective operating procedures and treatment processes. Indeed, the truly service-minded operator assists in adding to and improving the plant performance on a continuing basis.

Tomorrow's forgotten operator stopped learning yesterday

You can be an industrial operator tomorrow by beginning your learning today; or you can be a better operator, ready for advancement, by accelerating your learning today.

This training course, then, is your start towards a better tomorrow, both for you and for the industry and public who will receive better water from your efforts.

QUESTIONS

Place an "X" by the correct answer or answers. After you have answered all the questions, check your answers with those given at the end of the chapter on page 8. Reread any sections you did not understand and then proceed to the next section. You are your own teacher in this training program, and *YOU* should decide when you understand the material and are ready to continue with new material.

EXAMPLE

This is a training course on

________ A. Accounting

________ B. Engineering

___X___ C. Industrial Treatment Plant Operation

________ D. Salesmanship.

1.0A. Wastewater is the same thing as:

________ A. Rain

________ B. Soil

________ C. Sewage

________ D. Condensation.

1.0B. What does an industrial operator do?

________ A. Collect samples.

________ B. Lubricate equipment.

________ C. Record data.

1.0C. Who employs Industrial Plant Operators?

________ A. Cities.

________ B. Sanitation districts.

________ C. Industries.

Check your answers on page 8.

1.1 YOUR PERSONAL TRAINING COURSE

Beginning on this page, you are embarking on a training course which has been carefully prepared to allow you to improve your knowledge of and ability to operate an industrial wastewater treatment plant. You will be able to proceed at your own pace; you will have an opportunity to learn a little or a lot about each topic. The course has been prepared this way to fit the various needs of operators, depending on what kind of plant you have or how much you need to learn about it. To study for certification examinations, you will have to cover all the material. You will never know everything about your plant or about the wastewater which flows through it, but you can begin to answer some very important questions about how and when certain things happen in the plant. You can also learn to manipulate your plant so that it operates at maximum efficiency.

1.2 WHAT DO YOU ALREADY KNOW?

If you already have some experience operating an industrial wastewater treatment plant, you may use the first chapter for a review. If you are relatively new to the industrial wastewater treatment field, this chapter will provide you with important background information. The remainder of this introductory chapter describes your role as a *PROTECTOR OF WATER QUALITY*, your *QUALIFICATIONS* to do your job, a little about manpower needs in the industrial wastewater treatment field, and some information on other *TRAINING OPPORTUNITIES*.

1.3 THE WATER QUALITY PROTECTOR: YOU

Historically Americans have shown a great lack of interest in the protection of their water resources. We have been content to think that "the solution to pollution is dilution." For years we were able to dump our wastes with little or no treatment back into the nearest *RECEIVING WATERS*.[2] As long as there was enough dilution water to absorb the waste material, nature took care of our disposal problems for us. As more and more towns and industry sprang up, waste loads increased until the natural purification processes could no longer do the job. Many waterways were converted into open sewers. Unfortunately, for many areas this did not signal the beginning of a clean-up campaign. It merely increased the frequency of the cry: "We don't have the money for a treatment plant," or the ever-popular, "If we make industries treat their wastes they will move to another state." Thus, the pollution of our waters increased.

POLLUTION
WATER QUALITY

Water quality protector

Within the last few years, we have seen many changes in this depressing picture. We now realize that we must give nature a hand by treating wastes before they are discharged. Adequate treatment of wastes will not only protect our health and that of our downstream neighbors; it can also increase property values, allow game fishing and various recreational uses to be enjoyed, and attract water-using industries to the area. Today we are seeing massive efforts being undertaken to control water pollution and improve water quality throughout the nation. This includes the efforts not only of your own industry, community, county and state, but also the federal government.

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[2] ***Receiving Water.** A stream, river, lake, or ocean into which treated or untreated wastewater is discharged.*

Great sums of public and private funds are now being invested in large, complex municipal and industrial wastewater treatment facilities to overcome this pollution; and you, the treatment plant operator, will play a key role in the battle. Without efficient operation of your plant, much of the research, planning, and building that has been done and will be done to accomplish the goals of water quality control in your area will be wasted. You are the difference between a facility and a performing unit. You are, in fact, a *WATER QUALITY PROTECTOR* on the front line of the water pollution battle.

Pollution

The receiving water quality standards and waste discharge requirements that your plant has been built to meet have been formulated to *PROTECT* the water users downstream from your plant. These uses may include domestic water supply, industrial water supply, agricultural water supply, stock and wildlife watering, propagation of fish and other aquatic and marine life, shellfish culture, swimming and other water contact sports, boating, esthetic enjoyment, hydroelectric power, navigation, and others.

Therefore, you have an obligation to the users of the water downstream, as well as to the people of your district or municipality and industry. You are the *KEY WATER QUALITY PROTECTOR* and must realize that you are in a responsible position.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 8.

1.3A Why must municipal and industrial wastewaters receive adequate treatment?

1.3B How did many receiving waters become polluted?

1.4. YOUR QUALIFICATIONS

The skill and ability required for your job depend to a large degree on the size and type of treatment plant where you are employed. You may work at a large modern treatment plant treating several complex industrial wastestreams and employing ten or more operators. In this case you are probably a specialist in one or more phases of the treatment process.

On the other hand, you may operate a small plant or pretreatment facility. You may be the only operator at the plant or, at best, have only one or two additional employees. If this is the case, you must be a "jack-of-all trades" because of the diversity of your tasks.

1.41 Your Job

To describe the operator's duties, let us start at the beginning. Let us say that the need for a new or improved wastewater treatment plant has long been recognized by your industry. The industry has allocated the funds to finance the project, and the consulting engineers have submitted plans and specifications. It is to the best interests of the industry and the consulting engineer that you be in on the ground floor planning. If it is a new plant, you should be present or at least available during the construction period in order to become completely familiar with the entire plant, including the equipment and machinery and their operation. This will provide you with the opportunity to relate your plant drawings to actual facilities.

You and the engineer should discuss how the treatment plant should best be run and the means of operation the designer had in mind when the plant was designed. If it is an old plant being remodeled, you are in a position to offer excellent advice to the consulting engineer. Your experience provides valuable technical knowledge concerning the characteristics of wastewater, its sources, and the limitations of the present facilities. Together with the consultant, you are a member of an expert team able to advise the industry.

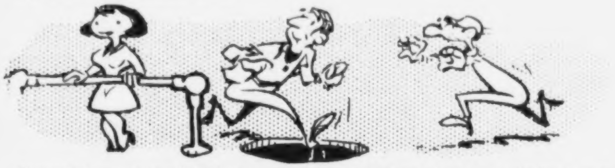
Once the plant is operating, you become an administrator. In a small plant your duties may not include supervision of personnel, but you are still in charge of records. You are responsible for operating the plant as efficiently as possible, keeping in

Visitors touring a treatment plant.

mind that the primary objective is to protect the receiving water quality by continuous and efficient plant performance. Without adequate, reliable records of every phase of operation, the effectiveness of your operation has not been documented (recorded).

You may also be the budget administrator. Most certainly you are in the best position to give advice on budget requirements, management problems, and future planning. You should be aware of the necessity for additional expenditures, including funds for plant enlargement, equipment replacement, and laboratory requirements. You should recognize and define such needs in sufficient time to inform the proper officials to enable them to accomplish early planning and budgeting.

You are in the field of public relations and must be able to explain the purpose and operation of your plant to visitors, civic organizations, school classes, representatives of news media, and even to city council or managers and directors of your industry. Public interest in water quality is increasing, and you should be prepared to conduct plant tours that will contribute to public acceptance and support. A well-guided tour for officials of regulatory agencies or other operators may provided these people with sufficient understanding of your plant to allow them to suggest helpful solutions to operational problems.



Special care and safety must be practiced when visitors are taken through your treatment plant. An accident could spoil all of your public relations efforts.

The appearance of your plant indicates to the visitor the type of operation you maintain. If the plant is dirty and rundown with tools and litter scattered about, you will be unable to convince your visitors that the plant is doing a good job. *YOUR RECORDS SHOWING A HIGH-QUALITY EFFLUENT*[3] *WILL MEAN NOTHING TO THESE VISITING CITIZENS AND OFFICIALS UNLESS YOUR PLANT APPEARS CLEAN AND WELL-MAINTAINED AND THE EFFLUENT LOOKS GOOD.*

Another aspect of your public relations duties is your dealings with the downstream water user. Unfortunately, the operator is often considered by the downstream user as a polluter rather than a water quality protector. Through a good public information program, backed by facts supported by reliable data, you can correct the impression held by the downstream user and establish "good neighbor" relations. This is indeed a challenge. Again,. you must understand that you hold a very responsible position and be aware that the sole purpose of the operation of your plant is to protect the downstream user, be that user a private property owner, another city or district, an industry, or a fisherman.

You are required to understand certain laboratory procedures in order to conduct various tests on samples of wastewater and receiving waters. On the basis of the data obtained from these tests, you may have to adjust the operation of the treatment plant to meet stream standards or discharge requirements.

As an operator you must have a knowledge of the complicated mechanical principles involved in many treatment mechanisms. In order to measure and control the wastewater flowing through the plant, you must have some understanding of hydraulics. Practical knowledge of electrical motors, circuitry, and controls is also essential.

CLEAN STREAM!

Clean Stream

Safety is a very important operator responsibility. Unfortunately too many operators take safety for granted. This is one reason why the wastewater treatment industry has one of the worst safety records of any industry. *YOU* have the responsibility to be sure that your treatment plant is a safe place to work and visit. Everyone must follow safe procedures and understand why safe procedures must be followed at all times. All operators must be aware of the safety hazards in and around treatment plants. You should plan or be a part of an active safety program. Chief operators frequently have the responsibility of training new operators and should encourage all operators to become certified.

Clearly then, the modern day industrial treatment plant operator must possess a broad range of qualifications.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 8.

1.4A Why is it important that the operator be present during the construction of a new plant?

1.4B How does the operator become involved in public relations?

1.5 MANPOWER NEEDS AND FUTURE JOB OPPORTUNITIES

The industrial treatment field, like so many others, is changing rapidly. New plants are being constructed, and old plants are being modified and enlarged to handle the wastewater from our growing population and to treat the new chemicals being produced by our space age technology. Operators, maintenance personnel, foremen, managers, instrumentation experts, and laboratory technicians are sorely needed.

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[3] *Effluent. Wastewater or other liquid – raw, partially or completely treated – flowing* FROM *a basin, treatment process, or treatment plant.*

A look at past records and future predictions indicates that wastewater treatment is a rapidly growing field. Municipalities employed approximately 20,000 operators in 1967 and over 67,000 operators in 1974. Industry employed approximately 3,500 operators in 1967 and around 12,000 plant operators by 1972.[4] In 1980 73,600 persons were employed in the wastewater treatment field and the need for new operators was estimated at 5,000 per year for every year up to the year 2000.[5] A report to Congress[6] in 1985 estimated that there were over 105,000 operators in the United States. The need for trained operators is increasing rapidly and is expected to continue in the future.

1.6 TRAINING YOURSELF TO MEET THE NEEDS

This training course is not the only one available to help you improve your abilities. The states have offered various types of both long- and short-term operator training through their health departments or water pollution control associations have provided training classes conducted by members of the associations, largely on a volunteer basis. State and local colleges have provided valuable training under their own sponsorship or in partnership with others. Many state, local and private agencies have conducted both long- and short-term training as well as interesting and informative seminars. The California Water Pollution Control Association as prepared two textbooks, one on laboratory procedures and one on mathematics.

Listed below are several very good references in the field of wastewater treatment plant operation that are frequently referred to throughout this course. The name in quotes represents the term usually used by operators when they mention the reference. Prices listed are those available when this manual was published and will probably increase in the future.

1. *"MOP 11." OPERATION OF WASTEWATER TREATMENT PLANTS,* WPCF Manual of Practice No. 11, Publications Order Department, Water Pollution Control Federation, Order No. M0012 0H0. Price $29.00 to members; $37.50 to others.

2. *"NEW YORK MANUAL." MANUAL OF INSTRUCTION FOR WASTEWATER TREATMENT PLANT OPERATORS,* distributed in New York by the New York State Department of Health, Office of Public Health Education, Water Pollution Control Board. Distributed outside of New York State by Health Education Service, P.O. Box 7126, Albany, New York 12224. Price $6.60.

3. *"TEXAS MANUAL." MANUAL OF WASTEWATER TREATMENT,* prepared by Texas Water Utilities Association. Obtainable from Texas Water Utilities Association, 6521 Burnet Lane, Austin, Texas 78757. Price $18.00, plus $1.15 postage.

These publications cover the entire field of treatment plant operation. At the end of many of the chapters yet to come, lists of other references will be provided.

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[4] *Data contained in this paragraph were obtained from "Manpower and Training Needs in Water Pollution Control," Report of the Department of the Interior, Federal Water Pollution Control Administration to the Congress of the United States, Senate Document No. 49, 90th Congress, First Session, Washington, D.C., 1967 and from "Study of Municipal Wastewater Treatment Plant Manpower and Training Needs and Resources," Municipal Permits and Operations Division, Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C., 1974.*

[5] *Bryant, James O., "Manpower Needs in Wastewater Treatment and Collection Systems for the Years 1980-2000." Paper presented at the Third Annual NETA National Conference and Workshop, Seattle, Washington, August 11, 1981.*

[6] *"Report to Congress on Training for Operators of Publicly Owned Wastewater Treatment Plants." Office of Municipal Pollution Control, U.S. Environmental Protection Agency, Washington, DC 20460, February 1985.*

SUGGESTED ANSWERS

Chapter 1. THE INDUSTRIAL PLANT OPERATOR

You are not expected to have the exact answer suggested for questions requiring written answers, but you should have the correct idea. The numbering of the questions refers to the section in the manual where you can find the information to answer the questions. Answers to questions numbered 1.0 can be found in Section 1.0, What is an Industrial Plant Operator?

Answers to questions on page 4.

1.0A. C

1.0B. A, B, C

1.0C. C

Answers to questions on page 5.

1.3A. Municipal and industrial wastewaters must receive adequate treatment to protect receiving water users.

1.3B. Receiving waters became polluted by a lack of public concern for the impact of waste discharges and by discharging wastewater into a receiving water beyond its natural purification capacity.

Answers to questions on page 6.

1.4A The operator should be present during the construction of a new plant in order to become familiar with the plant before the operator begins operating it.

1.4B The operator becomes involved in public relations by explaining the purpose and operation of the plant to visitors, civic organizations, newspaper people, and supervisors.

DIRECTIONS FOR WORKING OBJECTIVE TEST

Chapter 1. THE INDUSTRIAL PLANT OPERATOR

1. You have been provided with a special answer sheet for each chapter. Be sure you follow the special directions provided with the answer sheets. If you lose an answer sheet or have any problems, please notify the Project Director.

2. Mark your answers on the answer sheet with a dark lead pencil. Do not use ink.

   For example, Question 2 has three correct answers (1, 2 and 3). Therefore, you should place a mark under Columns 1, 2 and 3 on the answer sheet.

   Questions 4 through 7 are true or false questions. If a question is true, then mark Column 1, and if false mark Column 2. The correct answer to Question 4 is true; therefore, place a mark in Column 1.

   Please mark your answers in your workbook for your record because answer sheets will not be returned to you.

3. Mail answer sheet to the Project Director immediately after you have completed the test.

4. Answer sheets may be folded (but not into more than 3 equal parts) and mailed in a 4 x 9½ standard white envelope.

INDUSTRIAL WASTE TREATMENT

IMPORTANT

PLEASE READ INSTRUCTIONS ON REVERSE SIDE BEFORE COMPLETING THIS FORM.

OFFICE USE ONLY DO NOT MARK ●

Name: Operator Joe B
Last First MI

Address: 711 Main Street
Clearwater Ca 01234
City State Zip Code

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
9	8	7	6	5	4	3	2	1	0	1
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	●	⓪
①	①	①	①	①	①	①	①	●	①	●
②	②	②	②	②	②	②	●	②	②	②
③	③	③	③	③	③	●	③	③	③	③
④	④	④	④	④	●	④	④	④		④
⑤	⑤	⑤	⑤	●	⑤	⑤	⑤	⑤		⑤
⑥	⑥	⑥	●	⑥	⑥	⑥	⑥	⑥		⑥
⑦	⑦	●	⑦	⑦	⑦	⑦	⑦	⑦		⑦
⑧	●	⑧	⑧	⑧	⑧	⑧	⑧	⑧		⑧
●	⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨		⑨

Mail to:
Professor Kenneth Kerri
California State University, Sacramento
6000 J Street
Sacramento, California 95819

FOLD --

IMPORTANT DIRECTIONS FOR MARKING ANSWERS

Use black lead pencil only (# 2 or softer).
Make heavy black marks that fill the circle completely.
Erase clearly any answer you wish to change.
Make no stray marks on this answer sheet.

SAMPLE

Do Not Use

1. **MULTIPLE CHOICE QUESTIONS:** Fill in the correct answers. If 2 and 3 are correct for question 1, mark:

   1 2 3 4 5
   1 Ⓣ ● ● ○ ○

2. **TRUE–FALSE QUESTIONS:** If true, fill in the circle in column 1; if false, fill in column 2. If question 3 is true, mark:

   1 2 3 4 5
   3 ● Ⓕ ○ ○ ○

EXAMPLE

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
1	2	3	4	5	6	7	8	9	0	1
⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	⓪	●	⓪
●	①	①	①	①	①	①	①	①	①	●
②	●	②	②	②	②	②	②	②	②	②
③	③	●	③	③	③	③	③	③	③	③
④	④	④	●	④	④	④	④	④		④
⑤	⑤	⑤	⑤	●	⑤	⑤	⑤	⑤		⑤
⑥	⑥	⑥	⑥	⑥	●	⑥	⑥	⑥		⑥
⑦	⑦	⑦	⑦	⑦	⑦	●	⑦	⑦		⑦
⑧	⑧	⑧	⑧	⑧	⑧	⑧	●	⑧		⑧
⑨	⑨	⑨	⑨	⑨	⑨	⑨	⑨	●		⑨

NCS Trans-Optic® 05-16451-1098765 A2803

FOLD --

	1	2	3	4	5
1	Ⓣ	Ⓕ	○	○	○
2	Ⓣ	Ⓕ	○	○	○
3	Ⓣ	Ⓕ	○	○	○
4	Ⓣ	Ⓕ	○	○	○
5	Ⓣ	Ⓕ	○	○	○
6	Ⓣ	Ⓕ	○	○	○
7	Ⓣ	Ⓕ	○	○	○
8	Ⓣ	Ⓕ	○	○	○
9	Ⓣ	Ⓕ	○	○	○
10	Ⓣ	Ⓕ	○	○	○
11	Ⓣ	Ⓕ	○	○	○
12	Ⓣ	Ⓕ	○	○	○
13	Ⓣ	Ⓕ	○	○	○
14	Ⓣ	Ⓕ	○	○	○
15	Ⓣ	Ⓕ	○	○	○
16	Ⓣ	Ⓕ	○	○	○
17	Ⓣ	Ⓕ	○	○	○
18	Ⓣ	Ⓕ	○	○	○
19	Ⓣ	Ⓕ	○	○	○
20	Ⓣ	Ⓕ	○	○	○
21	Ⓣ	Ⓕ	○	○	○
22	Ⓣ	Ⓕ	○	○	○
23	Ⓣ	Ⓕ	○	○	○
24	Ⓣ	Ⓕ	○	○	○
25	Ⓣ	Ⓕ	○	○	○
26	Ⓣ	Ⓕ	○	○	○
27	Ⓣ	Ⓕ	○	○	○
28	Ⓣ	Ⓕ	○	○	○
29	Ⓣ	Ⓕ	○	○	○
30	Ⓣ	Ⓕ	○	○	○
31	Ⓣ	Ⓕ	○	○	○
32	Ⓣ	Ⓕ	○	○	○
33	Ⓣ	Ⓕ	○	○	○
34	Ⓣ	Ⓕ	○	○	○
35	Ⓣ	Ⓕ	○	○	○
36	Ⓣ	Ⓕ	○	○	○
37	Ⓣ	Ⓕ	○	○	○
38	Ⓣ	Ⓕ	○	○	○
39	Ⓣ	Ⓕ	○	○	○
40	Ⓣ	Ⓕ	○	○	○
41	Ⓣ	Ⓕ	○	○	○
42	Ⓣ	Ⓕ	○	○	○
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44	Ⓣ	Ⓕ	○	○	○
45	Ⓣ	Ⓕ	○	○	○
46	Ⓣ	Ⓕ	○	○	○
47	Ⓣ	Ⓕ	○	○	○
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49	Ⓣ	Ⓕ	○	○	○
50	Ⓣ	Ⓕ	○	○	○
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52	Ⓣ	Ⓕ	○	○	○
53	Ⓣ	Ⓕ	○	○	○
54	Ⓣ	Ⓕ	○	○	○
55	Ⓣ	Ⓕ	○	○	○
56	Ⓣ	Ⓕ	○	○	○
57	Ⓣ	Ⓕ	○	○	○
58	Ⓣ	Ⓕ	○	○	○
59	Ⓣ	Ⓕ	○	○	○
60	Ⓣ	Ⓕ	○	○	○

OBJECTIVE TEST

Chapter 1. THE INDUSTRIAL PLANT OPERATOR

Please mark correct answers on the answer sheet. There may be more than one correct answer to each question.

1. The used water and solids from a community that flow to a treatment plant are called ______________?
   1. Effluent
   2. Mixed Liquor
   3. Sludge
   4. Wastewater
2. Receiving water uses protected by an operator include
   1. Boating.
   2. Drinking water supply.
   3. Fishing.
   4. None of these
3. What kinds of jobs are available in the industrial treatment field in addition to those available for operators?
   1. Foremen
   2. Instrumentation experts
   3. Laboratory technicians
   4. Maintenance personnel
   5. Manager

TRUE OR FALSE:

4. In many treatment plants the operator must be a "jack-of-all-trades."
   1. True
   2. False
5. A treatment plant operator is a *WATER QUALITY* protector.
   1. True
   2. False
6. Plant visitors are impressed by records showing efficient plant operation, and their opinions are never influenced by the appearance of the plant and grounds.
   1. True
   2. False
7. After finishing this program, an operator will need to continue to study in order to keep pace with changes occurring in the field.
   1. True
   2. False

END OF OBJECTIVE TEST

CHAPTER 2

ACTIVATED SLUDGE

Pure Oxygen Plants and Operational Control Options

by

Ross Gudgel

and

Larry Peterson

OPERATION OF WASTEWATER TREATMENT PLANTS

Volume I, Chapter 8
Package Plants and Oxidation Ditches

OPERATION OF WASTEWATER TREATMENT PLANTS

Volume II, Chapter 11
Operation of Conventional Activated Sludge Plants

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NOTE: The following Tables of Contents for the Activated Sludge chapters in *OPERATION OF WASTEWATER TREATMENT PLANTS* are provided for your information in case you wish to learn more about the activated sludge process.

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OPERATION OF WASTEWATER TREATMENT PLANTS

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INDUSTRIAL WASTE TREATMENT

OBJECTIVES

Chapter 2. ACTIVATED SLUDGE

Pure Oxygen Plants and Operational Control Options

Following completion of Chapter 2, you should be able to:

1. Safely operate and maintain a pure oxygen activated sludge plant,
2. Review the plans and specifications for a pure oxygen system,
3. Describe the various methods of determining return sludge and waste sludge rates and select the best method for your plant,
4. Operate an activated sludge process that must treat both municipal and industrial wastes,
5. Operate an activated sludge process that must treat strictly an industrial waste, and
6. Operate an activated sludge process to produce a nitrified effluent.

GLOSSARY

Chapter 2. ACTIVATED SLUDGE

ABSORPTION (ab-SORP-shun) ABSORPTION

Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACTIVATED SLUDGE (ACK-ta-VATE-ed sluj) ACTIVATED SLUDGE

Sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, fungi, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.

ACTIVATED SLUDGE PROCESS (ACK-ta-VATE-ed sluj) ACTIVATED SLUDGE PROCESS

A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.

ADSORPTION (add-SORP-shun) ADSORPTION

The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.

AERATION LIQUOR (air-A-shun) AERATION LIQUOR

Mixed liquor. The contents of the aeration tank including living organisms and material carried into the tank by either untreated wastewater or primary effluent.

AERATION TANK (air-A-shun) AERATION TANK

The tank where raw or settled wastewater is mixed with return sludge and aerated. The same as aeration bay, aerator, or reactor.

AEROBES AEROBES

Bacteria that must have molecular (dissolved) oxygen (DO) to survive.

AEROBIC DIGESTION (AIR-O-bick) AEROBIC DIGESTION

The breakdown of wastes by microorganisms in the presence of dissolved oxygen. Waste sludge is placed in a large aerated tank where aerobic microorganisms decompose the organic matter in the sludge. This is an extension of the activated sludge process.

AGGLOMERATION (a-GLOM-er-A-shun) AGGLOMERATION

The growing or coming together of small scattered particles into larger flocs or particles which settle rapidly. Also see FLOC.

AIR LIFT AIR LIFT

A special type of pump. This device consists of a vertical riser pipe submerged in the wastewater or sludge to be pumped. Compressed air is injected into a tail piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An air-lift pump works similar to the center stand in a percolator coffee pot.

ALIQUOT (AL-li-kwot) ALIQUOT

Portion of a sample.

AMBIENT TEMPERATURE (AM-bee-ent) AMBIENT TEMPERATURE

Temperature of the surroundings.

ANAEROBES ANAEROBES

Bacteria that do not need molecular (dissolved) oxygen (DO) to survive.

BACTERIAL CULTURE (back-TEAR-e-al) BACTERIAL CULTURE

In the case of activated sludge, the bacterial culture refers to the group of bacteria classed as *AEROBES,* and facultative organisms, which covers a wide range of organisms. Most treatment processes in the United States grow facultative organisms which utilize the carbonaceous (carbon compounds) BOD. Facultative organisms can live when oxygen resources are low. When "nitrification" is required, the nitrifying organisms are *OBLIGATE AEROBES* (require oxygen) and must have at least 0.5 mg/*L* of dissolved oxygen throughout the whole system to function properly.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

BENCH SCALE ANALYSIS BENCH SCALE ANALYSIS

A method of studying different ways of treating wastewater and solids on a small scale in a laboratory.

BIOMASS (BUY-o-MASS) BIOMASS

A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris. This mass may be formed for, or function as, the protection against predators and storage of food supplies. Also see ZOOGLEAL MASS.

BULKING (BULK-ing) BULKING

Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.

CILIATES (SILLY-ates) CILIATES

A class of protozoans distinguished by short hairs on all or part of their bodies.

COAGULATION (ko-AGG-you-LAY-shun) COAGULATION

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, and draining or filtering.

COMPOSITE (PROPORTIONAL) SAMPLE (com-POZ-it) COMPOSITE (PROPORTIONAL) SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

CONING (CONE-ing) CONING

Development of a cone-shaped flow of liquid, like a whirlpool, through sludge. This can occur in a sludge hopper during sludge withdrawal when the sludge becomes too thick. Part of the sludge remains in place while liquid rather than sludge flows out of the hopper. Also called "coring."

CONTACT STABILIZATION CONTACT STABILIZATION

Contact stabilization is a modification of the conventional activated sludge process. In contact stabilization, two aeration tanks are used. One tank is for separate re-aeration of the return sludge for at least four hours before it is permitted to flow into the other aeration tank to be mixed with the primary effluent requiring treatment.

CRYOGENIC (cry-o-JEN-nick) CRYOGENIC

Low temperature.

DENITRIFICATION DENITRIFICATION

A condition that occurs when nitrite or nitrate ions are reduced to nitrogen gas and bubbles are formed as a result of this process. The bubbles attach to the biological flocs and float the flocs to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers.

DIFFUSED-AIR AERATION DIFFUSED-AIR AERATION

A diffused air activated sludge plant takes air, compresses it, and then discharges the air below the water surface of the aerator through some type of air diffusion device.

DIFFUSER DIFFUSER

A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DISSOLVED OXYGEN DISSOLVED OXYGEN

Molecular oxygen dissolved in water or wastewater, usually abbreviated DO.

ENDOGENOUS (en-DODGE-en-us) ENDOGENOUS

A reduced level of respiration (breathing) in which organisms break down compounds within their own cells to produce the oxygen they need.

F/M RATIO F/M RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\text{ lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\text{ lbs/gal}}$$

or

$$= \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

FACULTATIVE (FACK-ul-TAY-tive) FACULTATIVE

Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, facultative bacteria can live under aerobic or anaerobic conditions.

FILAMENTOUS BACTERIA (FILL-a-MEN-tuss) FILAMENTOUS BACTERIA

Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.

FLIGHTS FLIGHTS

Scraper boards, made from redwood or other rot-resistant woods or plastic, used to collect and move settled sludge or floating scum.

FLOC FLOC

Groups or clumps of bacteria that have come together and formed a cluster. Found in aeration tanks and secondary clarifiers.

FLOCCULATION (FLOCK-you-LAY-shun) FLOCCULATION

The gathering together of fine particles to form larger particles.

FOOD/MICROORGANISM RATIO FOOD/MICROORGANISM RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\text{ lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\text{ lbs/gal}}$$

or

$$= \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

Commonly abbreviated F/M Ratio.

HEADER HEADER

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "manifold."

INTERFACE INTERFACE

The common boundary layer between two fluids such as a gas (air) and a liquid (water) or a liquid (water) and another liquid (oil).

MCRT MCRT

Mean **C**ell **R**esidence **T**ime, days. An expression of the average time that a microorganism will spend in the activated sludge process.

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lbs/day}}$$

MLSS MLSS

Mixed **L**iquor **S**uspended **S**olids, mg/*L*. Suspended solids in the mixed liquor of an aeration tank.

MLVSS
MLVSS

Mixed **L**iquor **V**olatile **S**uspended **S**olids, mg/*L*. The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.

MANIFOLD
MANIFOLD

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "header."

MEAN CELL RESIDENCE TIME (MCRT)
MEAN CELL RESIDENCE TIME (MCRT)

An expression of the average time that a microorganism will spend in the activated sludge process.

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lbs/day}}$$

MECHANICAL AERATION
MECHANICAL AERATION

The use of machinery to mix air and water so that oxygen can be absorbed into the water. Some examples are: paddle wheels, mixers, or rotating brushes to agitate the surface of an aeration tank; pumps to create fountains; and pumps to discharge water down a series of steps forming falls or cascades.

MICROORGANISMS (micro-ORGAN-is-ums)
MICROORGANISMS

Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

MIXED LIQUOR
MIXED LIQUOR

When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank. Mixed liquor also may refer to the contents of mixed aerobic or anaerobic digesters.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS)
MIXED LIQUOR SUSPENDED SOLIDS (MLSS)

Suspended solids in the mixed liquor of an aeration tank.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)
MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)

The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.

MOVING AVERAGE
MOVING AVERAGE

To calculate the moving average for the last 7 days, add up the values for the last 7 days and divide by 7. Each day add the most recent day to the sum of values and subtract the oldest value. By using the 7-day moving average, each day of the week is always represented in the calculations.

NITRIFICATION (NYE-tri-fi-KAY-shun)
NITRIFICATION

A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

OXIDATION (ox-i-DAY-shun)
OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances. The opposite of REDUCTION.

POLYELECTROLYTE (POLY-electro-light)
POLYELECTROLYTE

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polymer."

POLYMER (POLY-mer)
POLYMER

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polymers may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polymers consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polyelectrolyte."

PROTOZOA (pro-toe-ZOE-ah)
PROTOZOA

A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.

PURGE
PURGE

To remove a gas or vapor from a vessel, reactor, or confined space.

RAS RAS

Return Activated Sludge, mg/*L*. Settled activated sludge that is collected in the secondary clarifier and returned to the aeration basin to mix with incoming raw or primary settled wastewater.

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions in wastewater, sulfate compounds or elemental sulfur is reduced to odor-producing hydrogen sulfide (H_2S) or the sulfide ion (S^{-2}). The opposite of OXIDATION.

RETURN ACTIVATED SLUDGE (RAS) RETURN ACTIVATED SLUDGE (RAS)

Settled activated sludge that is collected in the secondary clarifier and returned to the aeration basin to mix with incoming raw or primary settled wastewater.

RISING SLUDGE RISING SLUDGE

Rising sludge occurs in the secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.

ROTIFERS (ROE-ti-fers) ROTIFERS

Microscopic animals characterized by short hairs on their front end.

SECCHI DISC (SECK-key) SECCHI DISC

A flat, white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded secchi disc reading.

SEIZING SEIZING

Seizing occurs when an engine overheats and a component expands to the point where the engine will not run. Also called "freezing."

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SHOCK LOAD SHOCK LOAD

The arrival at a plant of a waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and solids in the effluent. Organic or hydraulic overloads can cause a shock load.

SLUDGE AGE SLUDGE AGE

A measure of the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process.

$$\text{Sludge Age, days} = \frac{\text{Suspended Solids Under Aeration, lbs or kg}}{\text{Suspended Solids Added, lbs/day or kg/day}}$$

SLUDGE DENSITY INDEX (SDI) SLUDGE DENSITY INDEX (SDI)

This test is used in a way similar to the Sludge Volume Index (SVI) to indicate the settleability of a sludge in a secondary clarifier or effluent. SDI = 100/SVI. Also see SLUDGE VOLUME INDEX (SVI).

SLUDGE VOLUME INDEX (SVI) SLUDGE VOLUME INDEX (SVI)

This is a test used to indicate the settling ability of activated sludge (aeration solids) in the secondary clarifier. The test is a measure of the volume of sludge compared to its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of the sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.

$$\text{SVI} = \frac{\text{Wet Settled Sludge, ml}}{\text{Dried Sludge Solids, mg}} \times 1000$$

STABILIZED WASTE STABILIZED WASTE

A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

STEP-FEED AERATION STEP-FEED AERATION

Step-feed aeration is a modification of the conventional activated sludge process. In step aeration, primary effluent enters the aeration tank at several points along the length of the tank, rather than all of the primary effluent entering at the beginning or head of the tank and flowing through the entire tank.

STRIPPED GASES
STRIPPED GASES

Gases that are released from a liquid by bubbling air through the liquid or by allowing the liquid to be sprayed or tumbled over media.

SUPERNATANT (sue-per-NAY-tent)
SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.

TOC
TOC

Total **O**rganic **C**arbon. TOC measures the amount of organic carbon in water.

TURBIDITY METER
TURBIDITY METER

An instrument for measuring the amount of particles suspended in water. Precise measurements are made by measuring how light is scattered by the suspended particles. The normal measuring range is 0 to 100 and is expressed as Nephelometric Turbidity Units (NTU's).

VOLUTE (vol-LOOT)
VOLUTE

The spiral-shaped casing which surrounds a pump, blower, or turbine impeller and collects the liquid or gas discharged by the impeller.

WAS
WAS

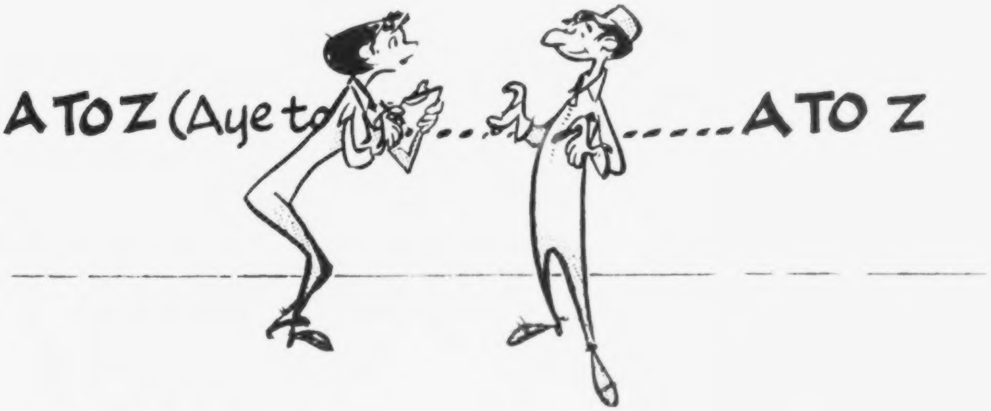
Waste **A**ctivated **S**ludge, mg/*L*. The excess growth of microorganisms which must be removed from the process to keep the biological system in balance.

WASTE ACTIVATED SLUDGE (WAS)
WASTE ACTIVATED SLUDGE (WAS)

The excess growth of microorganisms which must be removed from the process to keep the biological system in balance.

ZOOGLEAL MASS (ZOE-glee-al)
ZOOGLEAL MASS

Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes. These masses may be formed for or function as the protection against predators and for storage of food supplies. Also see BIOMASS.



CHAPTER 2. ACTIVATED SLUDGE

Pure Oxygen Plants and Operational Control Options

(Lesson 1 of 4 Lessons)

NOTE: Review Volume I, Chapter 8, and Volume II, Chapter 11, of *OPERATION OF WASTEWATER TREATMENT PLANTS* for additional information.

2.0 THE ACTIVATED SLUDGE PROCESS

Research and operational experience are gradually revealing how the activated sludge process treats wastes and how to control the process. One objective of this chapter is to provide operators with a better understanding of the factors that can upset an activated sludge process and how to control the process to produce a high quality effluent. Pure oxygen systems dissolve oxygen into wastewater with a high efficiency for use by microorganisms treating the wastes. This allows the use of smaller aeration (reactor) tanks than air activated sludge systems. Operators need greater skill and knowledge to operate pure oxygen systems than conventional systems.

Operation of either pure oxygen or conventional aeration activated sludge processes is very complex. The quality of your plant's effluent depends on the characteristics of the plant's influent flows and wastes, as well as how the actual process is controlled. Two very important factors are:

1. RETURN ACTIVATED SLUDGE (RAS) RATE, and
2. WASTE ACTIVATED SLUDGE (WAS) RATE.

Several methods have been developed to help operators select the proper rates. This chapter reviews some of these methods and their advantages and limitations. You must remember that each of these factors affects the others and the impact on all process variables must be considered before changing one variable.

Some NPDES permits require the removal of ammonia from plant effluents. Biological nitrification (converting ammonium (NH_4^+) to nitrate (NO_3^-) is the most effective way to remove ammonia unless total nitrogen removal is necessary. If total nitrogen removal is required, biological nitrification is the first step of the biological nitrification-denitrification approach to nitrogen removal. The biological nitrification process is an extension of the activated sludge process and is operated on the basis of the same concepts.

Industrial wastes are becoming more common in many municipal wastewaters. Whether you operate an activated sludge plant in a small town or a large city, you must know how to treat the industrial wastes that may be present with your municipal wastewaters. Many industries pretreat their own wastewaters before discharge to municipal collection systems while other industries treat all of their wastewaters rather than discharge into municipal collection systems. Whether you are treating strictly industrial wastewaters or a mixture of industrial and municipal wastewaters, this chapter will provide you with the information you need to know to safely treat these different types of wastewaters using the activated sludge process.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 94.

2.0A Why are pure oxygen systems used instead of conventional aeration methods?

2.0B What treatment process can be used to remove ammonium (NH_4^+) from wastewater, but not total nitrogen?

2.1 PURE OXYGEN

2.10 Description of Pure Oxygen Systems

The pure oxygen system (Fig. 2.1) is a modification of the activated sludge process (Fig. 2.2). The main difference is the method of supplying dissolved oxygen to the activated sludge process. In other activated sludge processes, air is compressed and released under water to produce an air-water *INTERFACE*[1] that transfers oxygen into the water (dissolved oxygen). If compressed air is not used, surface aerators agitate the water surface to drive air into the water (dissolved oxygen) to obtain the oxygen transfer. In the pure oxygen system, the only real differences are that pure oxygen rather than air is released below the surface or driven into the water by means of surface aerators and the aerators are covered.

In the pure oxygen system, oxygen is first separated from the air to produce relatively high-purity oxygen (90 to 98 percent oxygen). Pure oxygen is applied to the wastewater as a source of oxygen for the microorganisms treating the wastes. As with forced-air activated sludge systems, the pure oxygen must be driven into the water. This is accomplished by a diffuser mechanism or by mechanical agitation consisting of *TURBULENT MIXERS*[2] and surface aerators. The agitators also supply the energy to mix the reactor (aeration tank) contents to distribute the waste food (measured as BOD or COD) to the activated sludge microorganisms in the mixed liquor suspended solids (MLSS) and to prevent buildup of MLSS deposits in the reactor.

The pure oxygen reactors are staged (divided into two to five sections by baffles as shown in the three-stage system on Fig. 2.3) and are completely covered to provide a gas-tight enclosure. The wastewater, return sludge, and oxygen are fed into the first stage. The mixed liquor and atmosphere above it flow in the same direction from the first stage to the last.

---

[1] ***Interface.*** *The common boundary layer between two fluids such as a gas (air) and a liquid (water) or a liquid (water) and another liquid (oil).*

[2] ***Turbulent Mixers.*** *Devices that mix air bubbles and water and cause turbulence to dissolve oxygen in water.*

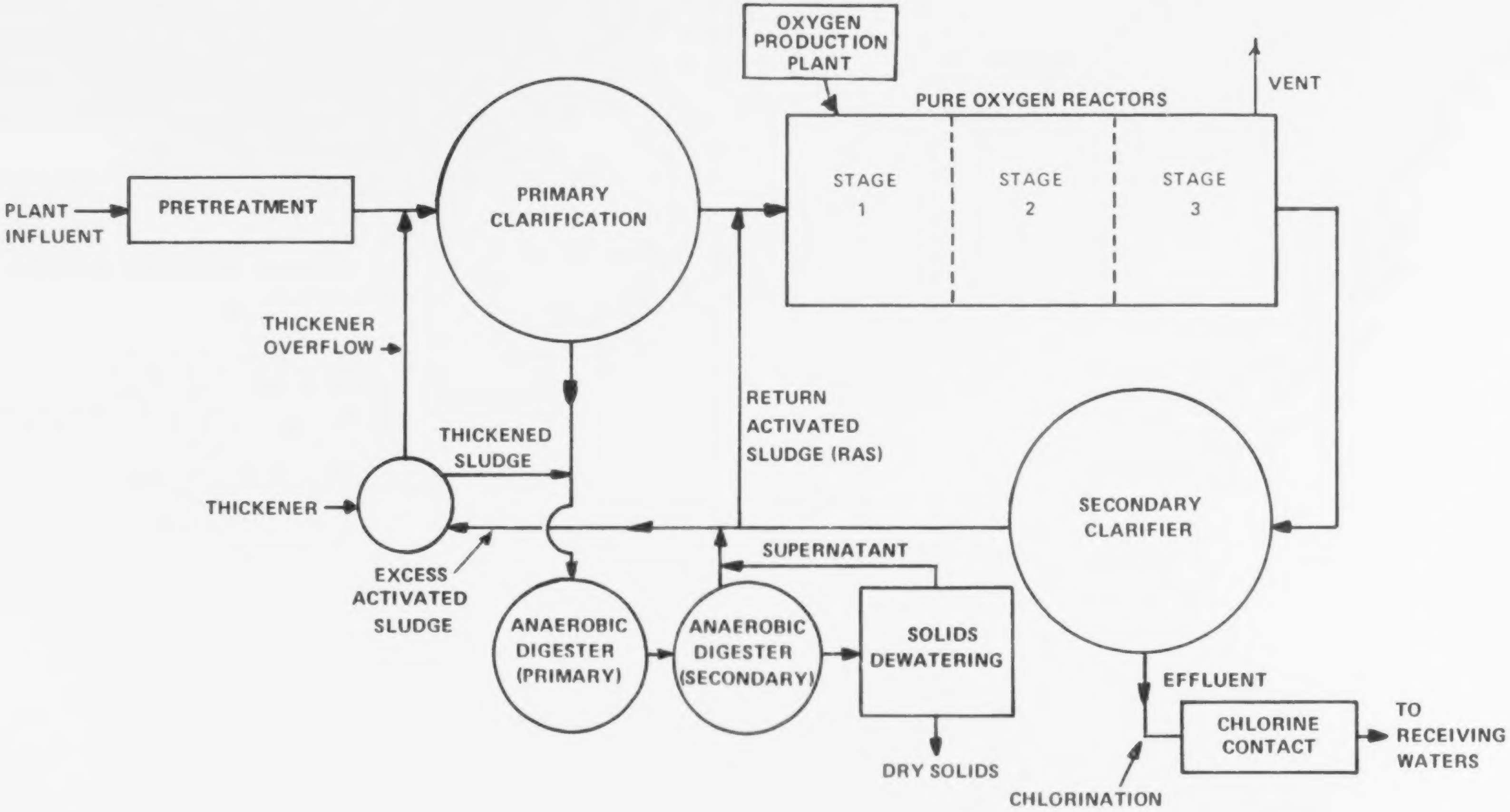

OXYGEN PRODUCTION PLANT
PURE OXYGEN REACTORS
VENT
STAGE 1
STAGE 2
STAGE 3
PLANT INFLUENT
PRETREATMENT
PRIMARY CLARIFICATION
THICKENER OVERFLOW
RETURN ACTIVATED SLUDGE (RAS)
THICKENED SLUDGE
THICKENER
SECONDARY CLARIFIER
SUPERNATANT
EXCESS ACTIVATED SLUDGE
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SOLIDS DEWATERING
EFFLUENT
CHLORINE CONTACT
TO RECEIVING WATERS
DRY SOLIDS
CHLORINATION

Fig. 2.1 Plan layout of a typical pure oxygen activated sludge plant

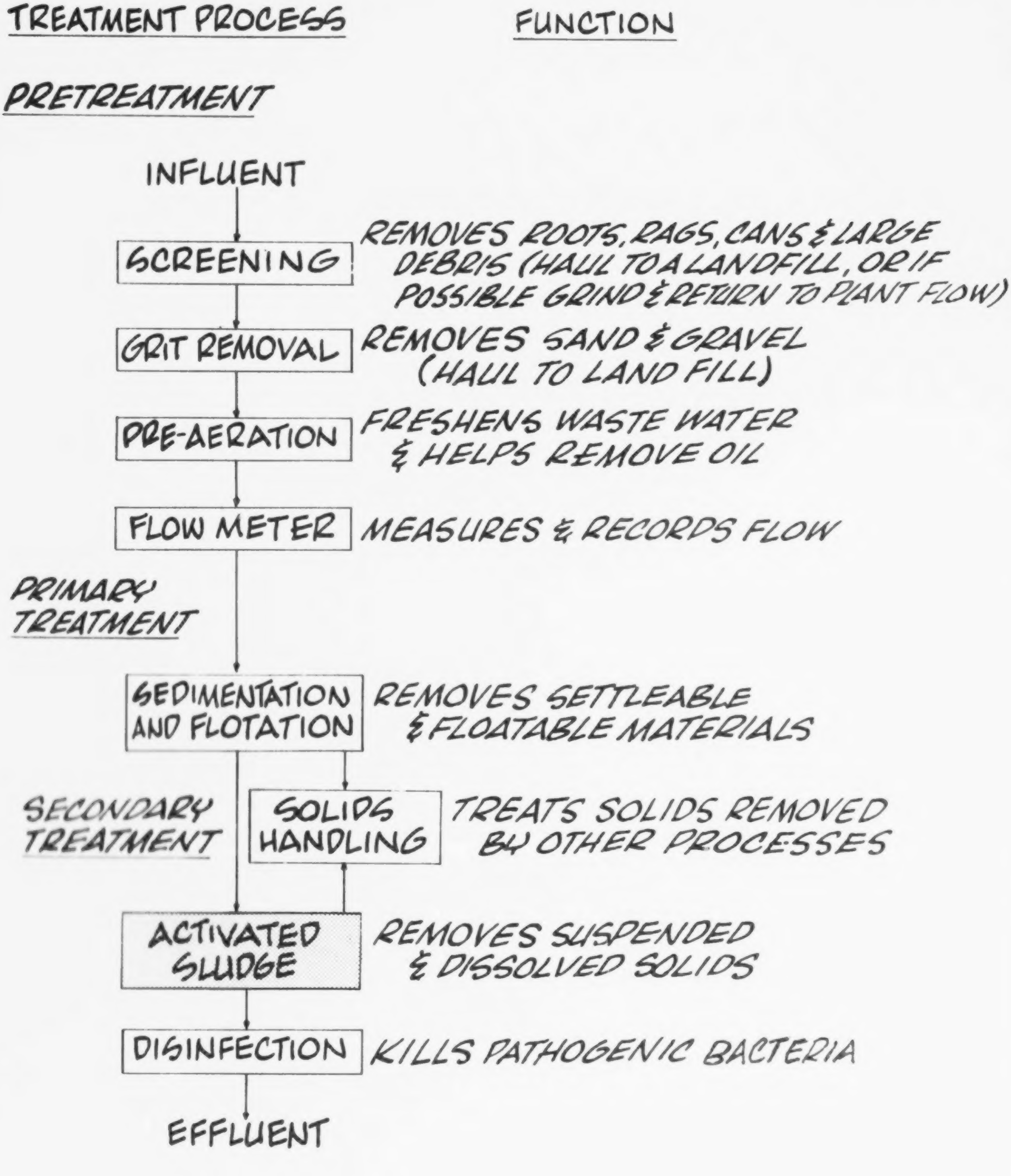

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
ACTIVATED SLUDGE
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC BACTERIA
EFFLUENT

Fig. 2.2 Flow diagram of a typical plant

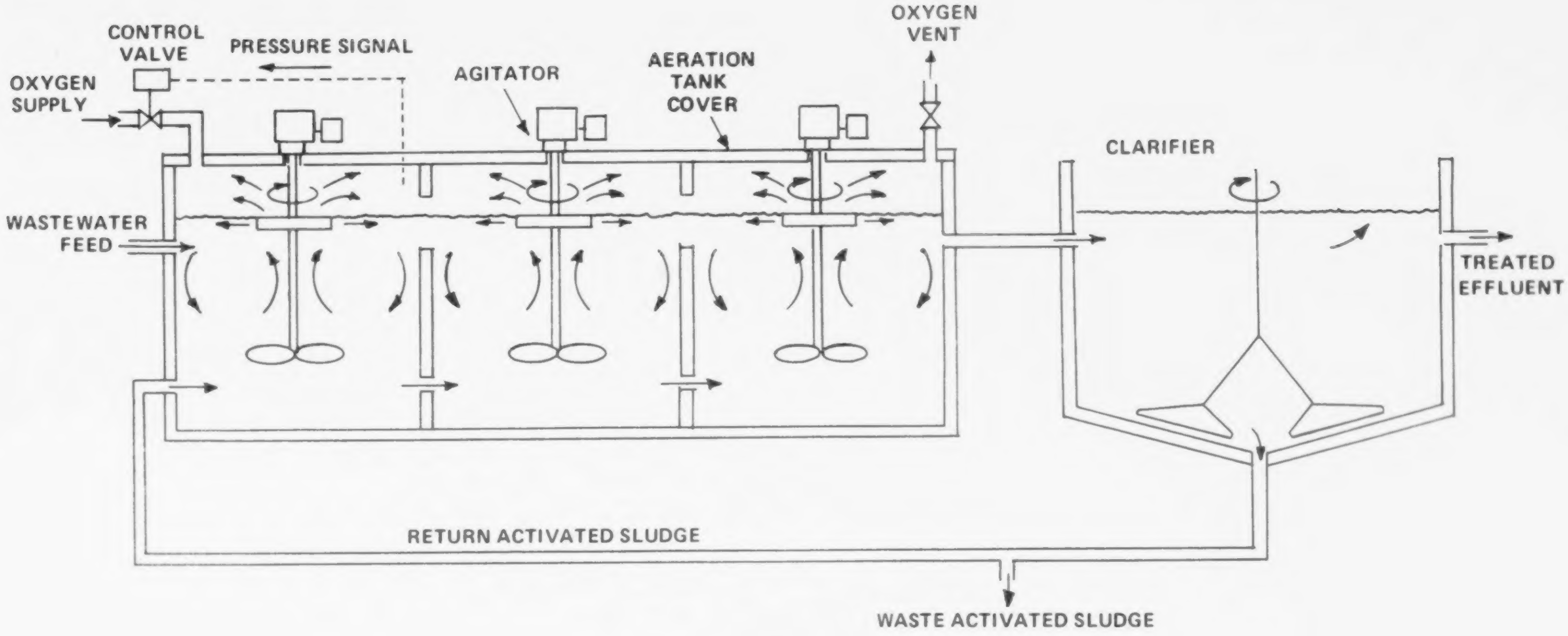

OXYGEN SUPPLY
CONTROL VALVE
PRESSURE SIGNAL
AGITATOR
AERATION TANK COVER
OXYGEN VENT
CLARIFIER
WASTEWATER FEED
TREATED EFFLUENT
RETURN ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE

Fig. 2.3 Schematic diagram of pure oxygen system with surface aerators (3 stages shown)

(Permission of Union Carbide Corporation)

When pure oxygen is driven into the water, it behaves similar to air and the bubbles rise to the water surface. During this rise to the surface, only a small portion of the oxygen is absorbed into the mixed liquor. Covering the reactor and sealing it from the outside atmosphere allows the oxygen that is not dissolved into the water (mixed liquor) to be used again. This contained gas over the water is still relatively high in oxygen concentration, the main contamination consisting of carbon dioxide gas given off by the respiration (breathing) of the activated sludge microorganisms and the nitrogen stripped from the incoming wastewater. The number of stages and the methods of contacting the liquid and oxygen vary from one system to another. In one type of design, the oxygen-rich gas that accumulates in the space between the mixed liquor water surface and the roof of the reactor is removed, compressed, and recycled back to the diffuser of the reactor. In another type of design, surface aerators are used to drive the oxygen-rich gas into the water. In deep reactors (40 feet or 12 m), the surface aerator device may also be equipped with an extended shaft and submerged impeller to keep the tank contents well mixed. A third type of design incorporates both submerged diffusers and surface aeration. Some reactors vent the excess oxygen along with the carbon dioxide. Uncovered reactors skim the surface sludge for wasting.

In all types of design, a valve opens automatically and admits more pure oxygen to the first-stage reactor whenever sufficient oxygen is removed from the gas space of the first-stage reactor to drop the pressure below the required 1 to 4 inches (2 to 10 cm) of water column pressure. This constantly replenishes the oxygen supply and the pressure is sufficient to force gas movement through the succeeding stages. This pressure prevents air from leaking into the reactors, diluting the oxygen concentration and possibly creating an explosive mixture. Oxygen leaking from a reactor can create an explosive condition on the roof or around the reactor. Potentially explosive conditions inside the reactor from a mixture of hydrocarbons and oxygen are avoided by an automatically activated analysis and purge system.

In each of the succeeding stages, the gas above the mixed liquid in that stage is reinjected into the mixed liquor of the same stage (by compressor or surface aerator). As the oxygen-rich gas passes from one stage to the next, the oxygen is used by the activated sludge microorganisms and the atmosphere becomes more and more diluted by the carbon dioxide produced by the organisms and nitrogen *STRIPPED*[3] from solution. The last stage in the reactor is equipped with a roof vent controlled by a valve mechanism that is called an oxygen vent valve. This valve vents gas from the last stage to the atmosphere and is normally set to vent gas when the oxygen concentration drops below 50 percent. As gas is vented from the last stage, more pure oxygen is released into the first stage to maintain the desired 1 to 4 inches (2 to 10 cm) of water column pressure.

Two methods are commonly used to produce pure oxygen. One is the **P**ressure **S**wing **A**bsorption (PSA) Oxygen Generating System and the other is the *CRYOGENIC*[4] Air Separation Method.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 94.

2.1A Why are the pure oxygen reactors staged?

2.1B How is the pure oxygen diluted as it passes from one stage to the next stage?

2.11 PSA (Pressure Swing Absorption) Oxygen Generating System (Fig. 2.4)

The PSA Oxygen Generating Systems are usually installed in smaller plants. They take air from the atmosphere and compress it to 30 to 60 psi (2 to 4 kg/sq cm) and cool the compressed air in a water-cooled heat exchanger called an after cooler. The after cooler condenses and removes the moisture from the air stream. Next the air passes through an adsorbent vessel filled with a molecular sieve. Under pressure, this molecular sieve has the ability to adsorb nitrogen and other impurities from the atmospheric air, thus allowing the remaining pure oxygen to be used in the reactor. While one adsorber vessel is separating air into oxygen and nitrogen, the other two vessels are in various stages of desorption (or cleanup). The cleanup cycle consists of depressurizing and *PURGING*[5] with some product oxygen. The last step involves pressurizing with compressed air before going back on stream. During this process, product oxygen is flowing continuously to the activated sludge plant.

The PSA unit can be turned down to 25 percent of its rated oxygen throughout without a significant loss of efficiency. Compressor and valve maintenance can be scheduled so as not to have more than one or two days of downtime per year by the use of multiple compressors. A backup tank of liquid provides oxygen after evaporation to handle peak loads or downtime oxygen demand. The switching valves are selected on the basis of their ability to withstand very severe conditions over long periods of time.

2.12 Cryogenic Air Separation Method (Fig. 2.5)

Oxygen produced by the cryogenic air separation method uses low temperature (cryogenic) or refrigeration principles to separate oxygen from air. Air is filtered, compressed, cooled to remove moisture, and then routed to the cold box or "cryo" plant tower. These towers are heavily insulated to conserve energy by minimizing heat leaks or losses. In Fig. 2.5 all the items contained in the dash-lined box are located in the "cryo" plant tower.

The reversing heat exchanger primarily removes carbon dioxide and water. This heat exchanger has two directional gas flows; one of air going into the tower and the other of nitrogen being exhausted to the atmosphere. As the flowing air removes carbon dioxide and water, ice will form in the heat exchanger and restrict the air flow through the heat exchanger. After several minutes of operation, a valve is activated that interchanges the gas stream flows by reversing the direction of flow. The nitrogen exhaust is routed through the inlet air pas-

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[3] *Stripped Gases. Gases that are released from a liquid by bubbling air through the liquid or by allowing the liquid to be sprayed or tumbled over media.*

[4] *Cryogenic (cry-o-JEN-nick). Low temperature.*

[5] *Purge. To remove a gas or vapor from a vessel, reactor or confined space.*

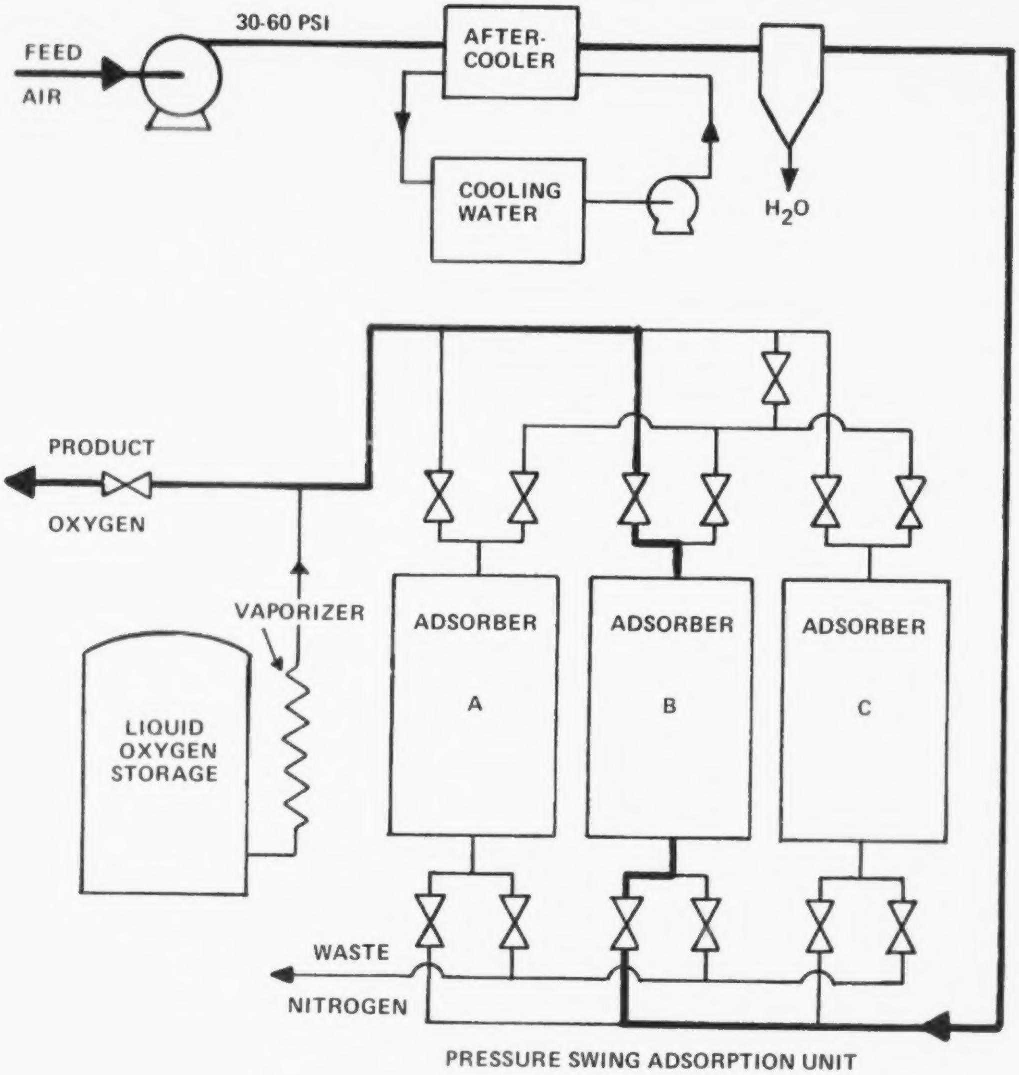
FEED
AIR
30-60 PSI
AFTER-COOLER
COOLING WATER
H_2O
PRODUCT
OXYGEN
VAPORIZER
LIQUID OXYGEN STORAGE
ADSORBER A
ADSORBER B
ADSORBER C
WASTE
NITROGEN
PRESSURE SWING ADSORPTION UNIT

Fig. 2.4 Flow diagram of a three-bed PSA (Pressure Swing Adsorption) oxygen generating system

(Permission of Union Carbide Corporation)

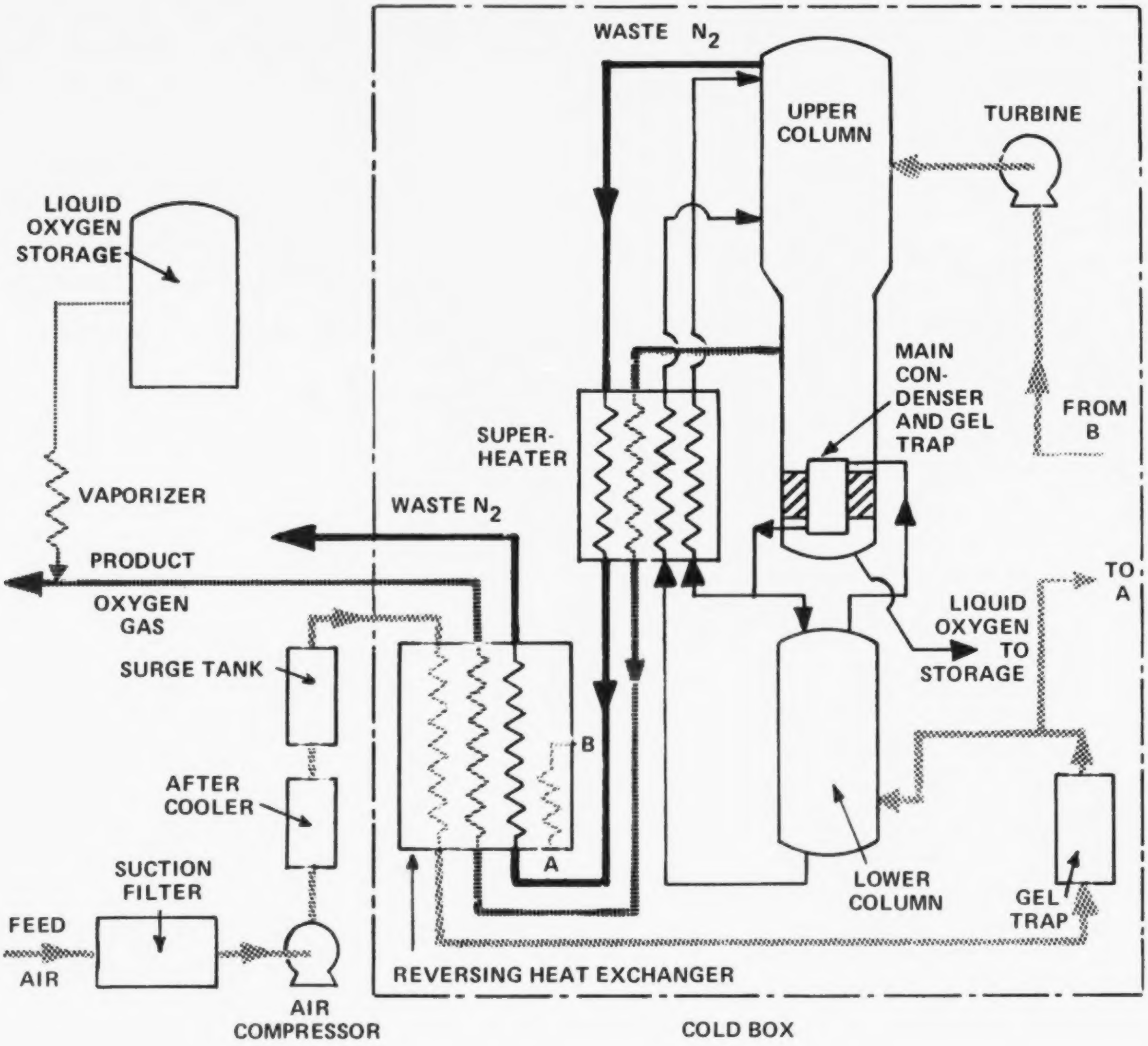
WASTE N_2
UPPER COLUMN
TURBINE
LIQUID OXYGEN STORAGE
MAIN CON-DENSER AND GEL TRAP
FROM B
SUPER-HEATER
VAPORIZER
WASTE N_2
PRODUCT
OXYGEN GAS
TO A
LIQUID OXYGEN TO STORAGE
SURGE TANK
B
AFTER COOLER
A
SUCTION FILTER
LOWER COLUMN
FEED
AIR
GEL TRAP
REVERSING HEAT EXCHANGER
AIR COMPRESSOR
COLD BOX

Fig. 2.5 Flow diagram of a cryogenic oxygen generating system

(Permission of Union Carbide Corporation)

sage and thaws the partially blocked passages. A small portion of the water and carbon dioxide leave as tiny ice particles. The inlet air then travels through the previous nitrogen exhaust side until once again the ice builds up in the passage. Again the valve is activated and switches the routes of the two gas flows. This cycle usually varies from five to twenty minutes depending on the system. The exiting pure oxygen is also heat exchanged against the incoming air. In this case, however, the passages are never switched. This allows the oxygen to remain at high purity (about 98 percent pure oxygen).

A silica gel trap absorbs any remaining moisture that may have gotten past the reversing heat exchanger. Trace hydrocarbons are also picked up by the gel trap. The clean, cold air is liquified and separated into oxygen and nitrogen by fractional distillation in a two column arrangement. The lower high pressure column produces pure liquid nitrogen to use as reflux (flow back) in the low pressure upper column. Nitrogen, the most volatile component of air, is taken from the top of the upper column. Pure oxygen, the less volatile component, is taken from near the bottom of the upper column. A 98 percent purity oxygen stream is sent to the activated sludge process after heat exchange against the incoming air to recover its refrigeration (cool incoming air). Refrigeration to run the process comes from expanding a portion of the cooled and cleaned incoming air through an expansion turbine before it enters the upper column.

Approximately three percent of the capacity of the oxygen plant is available as liquid oxygen. This liquid can be used to keep the stored liquid oxygen backup tank full and ready to supply oxygen during peak loads or plant start-up.

To start an *AMBIENT TEMPERATURE*[6] cryogenic plant producing oxygen without liquid oxygen requires about three to five days. If liquid oxygen is available, a few hours is all that is required to place the plant in production. The oxygen production rate of a plant is determined by the oxygen demand in the activated sludge plant. As less production is required, the oxygen plant air compressors are partially unloaded.

Cryogenic plants are usually shut down once a year for approximately five to seven days for maintenance. During this period the gel traps are warmed to drive off moisture and hydrocarbons. By the use of multiple compressors and operational maintenance thaws, this downtime can be reduced to two or three days per year. During downtime, oxygen vaporized from the backup liquid oxygen storage tank is used. Sometimes in larger plants more than one oxygen producing facility is supplied to minimize the use of backup liquid oxygen.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 94.

2.1C What two methods are commonly used to produce pure oxygen?

2.1D What does cryogenic mean?

2.1E How often and for how long are cryogenic plants shut down for maintenance?

2.13 Process and System Control

Pure oxygen systems may be used to supply oxygen to any of the activated sludge process modes — conventional, step-feed, complete mix or contact stabilization.

2.14 System Start-Up

Pure oxygen system start-up is basically much the same as starting conventional air systems. Individual components and starting procedures are usually outlined in the O&M manual or the manufacturer's literature. Take special care with the reactor because flow and organic loadings must be determined prior to start-up. Overloading or underloading may cause problems. Careful review of design data usually provides sufficient information to initially start the system. After start-up, the system is "fine tuned" to prevailing conditions in the wastewater.

2.15 Control Guidelines

1. *REACTOR VENT GAS* — A mixture of unused oxygen (about 5 to 10 percent of the oxygen supplied), inert gases and carbon dioxide is continually discharged from the last stage of the reactor. The vent purity, or percentage of oxygen contained in the mixture of gases, is an indicator of oxygen use efficiency. A low oxygen purity reading (25 percent or below) indicates that sufficient oxygen is not present and adequate BOD removal may not be accomplished. A high purity reading (50 percent or higher) indicates that too much oxygen is being wasted with the by-product gases. A manually controlled vent valve is adjusted to control vent purity. If purity is low, the valve could be opened further and closed down if purity is high. In normal operation (after start-up), "fine tuning" of this setting usually is not changed unless there is a drastic change in either the quantity or strength of the wastewater entering the plant.
2. *REACTOR GAS SPACE PRESSURE* — Gas space pressure is set by controlling the vent rate in the last stage. This will automatically establish the pressure level throughout the reactor. Gas pressure will vary to some extent within the reactor, dropping as more oxygen is vented and rising as venting is decreased or consumption is reduced. Pressure is usually preset at two inches (5 cm) water column in the first stage and the system will automatically feed oxygen at the required rates to maintain this condition. However, during high loading periods, the operator can increase oxygen transfer and production by increasing the pressure set point from 2 to 4 inches (5 to 10 cm) of water column, providing the vent valve setting is not changed. Relief valves on the first and last stage of each reactor prevent overpressurization. Similarly, during periods of unloading, a vacuum release provided by these same valves prevents a negative pressure.
3. *DISSOLVED OXYGEN* — A dissolved oxygen probe is sometimes located in the diversion box prior to the secondary clarifer or in the last stage of the reactor. It indicates the amount of DO in the mixed liquor. Typical oxygen systems usually operate with a DO range of 4 to 10 mg/*L* of dissolved oxygen. If the organic load increases over an extended period which would tend to drop the dissolved oxygen level below 4 mg/*L*, the operator should adjust the vent valve to a more open position which will increase oxygen production. Above a DO of 10 mg/*L*, the amount of oxygen being produced could be decreased if this is anticipated to be a long-term condition.

By measuring and monitoring these control guidelines, the operator can establish the most efficient treatment method on the basis of plant performance and experience. Operation of the secondary clarifiers, return rates, wasting rates and other control guidelines, are much the same for the pure oxygen system as they are for the conventional air activated sludge system.

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[6] *Ambient Temperature (Am-bee-ent). Temperature of the surroundings.*

2.16 Process Safety

Potentially explosive or flammable conditions can be present when pure oxygen gas is mixed with any hydrocarbon such as gasoline, fuel oil and lubricating oils. In addition to normal safety devices found on motors, compressors, electrical components and control mechanisms, the pure oxygen system uses safety devices to ensure process safety when working with oxygen gas. These safety devices are:

1. *L.E.L. (LOWER EXPLOSIVE LIMIT COMBUSTIBLE GAS DETECTOR)* — Indicates potential explosive conditions within the reactor, and analyzes samples collected from the first and last stage of each train in the reactor. Readings are made based on all components being analyzed as propane. If a hydrocarbon spill gets through the primary treatment system without being diverted and causes a reading of more than 25 percent of the L.E.L., an alarm will sound. The product valve from the oxygen system will shut down and air will automatically be directed to the reactor gas space to *PURGE*[7] the system. The purge will continue until normal readings are obtained. If the spill is so large that the L.E.L. continues to rise to the 50 percent level, in addition to an alarm sounding, an electrical restart of the purge blower will occur. The mixers will shut down to stop hydrocarbon stripping and they cannot be restarted until readings below the 10 percent L.E.L. are obtained.

   No electrical work is ever installed below the roof nor are there any metal-to-metal contact potentials present. The mixers pass through the roof through a water seal. This eliminates the potential for sparks and a source of ignition. By eliminating sources of ignition and any chance of ignitable mixtures, the chances of an explosion become virtually zero. To date the safety record at activated sludge plants using pure oxygen has been excellent. Also, having a deck (roof) over the reactor provides a safe and easily accessible place for maintenance work and further minimizes the chances of having accidents.

   One way to help prevent explosive conditions from developing is to install a Lower Explosive Limit (L.E.L.) Combustible Gas Detector in the plant headworks. This detector should trigger an alarm whenever hydrocarbons reach the headworks so action can be taken to prevent hydrocarbons from reaching reactors containing pure oxygen. Wastewater containing hydrocarbons can be diverted to emergency holding ponds if available.

2. *LIQUID OXYGEN (STORAGE TANK) LOW TEMPERATURE ALARM* — Provides an alarm and shutdown of the liquid storage system in the event heated water recirculation within the vaporizer reaches a low temperature level. A temperature monitor measures temperature levels of the oxygen gas and if the vapor falls below −10 degrees Fahrenheit (−23°C); an alarm will sound on the instrument panel. At an indication of −20 degrees Fahrenheit (−29°C), the liquid system will shut down until the temperature returns to normal conditions, but must be manually reset.

3. *EMERGENCY TRIP SWITCH* — In the event that any other unsafe condition should arise within the compressor system, liquid oxygen system or electrical panels, an emergency trip switch may be manually pulled. When pulled, the entire oxygen system shuts down and must be reset manually and each major piece of equipment restarted. This safety switch is not commonly used. It is only used as a last resort if safety systems fail or a major problem exists within the system which threatens the well being and the safety of personnel. This switch is usually located away from a source of danger. As with any treatment plant, the operator must follow safety precautions established by the manufacturers and design engineers. Caution and warning signs should be posted in areas where danger is present.

2.17 Operator Safety

Special safety rules must be applied when operating and maintaining pure oxygen systems because of the unique properties of high purity oxygen. Cold liquid oxygen (LOX) can cause skin burns. Always wear rubber gloves and protective clothing when taking liquid oxygen samples from columns. This is the only time operators need to handle liquid oxygen.

Pure oxygen supports and accelerates combustion more readily than air. Therefore, all types of hydrocarbons and other flammable materials must be kept from mixing with the oxygen. The following precautions are intended to eliminate the possibility of combustion and explosions.

1. Special non-hydrocarbon lubricants as specified by the manufacturer should be used for equipment in contact with oxygen.
2. Tools and equipment must be specially designed to be compatible for use in oxygen service.
3. Flammable materials must be kept far away from oxygen systems and storage tanks.
4. Grease and oil must be removed from tools and equipment by the use of a solvent such as chloroethane.
5. Smoking and open flames are prohibited near oxygen systems and storage tanks.

Liquid oxygen is delivered by specially designed trucks and transferred by specially trained technicians. Therefore, the chances of liquid oxygen spills are remote. If a liquid oxygen spill occurs, the liquid could saturate a combustible material and this material could ignite or explode. Ignition can be caused by hot objects, open flames, glowing cigarettes, embers, sparks, or impact such as might be caused by striking with a hammer, dropping a tool or scuffing with your heel. Typical combustible materials that are dangerous when saturated with spilled liquid oxygen include asphalt in black top pavements, humus in soil, oil or grease on concrete floors or pavements, articles of clothing, or *ANY OTHER SUBSTANCE THAT WILL BURN IN AIR*. Any equipment involving liquid oxygen should be constructed on a concrete pad to avoid the potential of soaking a black top surface with liquid oxygen.

Every possible effort must be made to prevent the spillage of liquid oxygen. If a spill does occur, the following procedures must be followed:

1. No one may set foot in any area still showing frost marks from an oxygen spill.
2. The affected area must be roped off as soon as possible. When rope, barricades and signs are not immediately available, someone must stay at the area to warn other persons of the hazard.
3. No tank car or truck movements are allowed over an area still showing frost marks from an oxygen spill.

These procedures apply to any oxygen spillage on any surface, including cement, gravel, black top, or dirt either inside buildings or outdoors. *NO ONE IS ALLOWED TO STEP ON ANY AREAS WHERE FROST MARKS EXIST FROM A SPILL.*

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[7] *Purge. Remove pure oxygen from the reactors and attempt to dilute hydrocarbon vapors to below the explosive limit.*

2.18 Pure Oxygen System Maintenance

Maintenance of a pure oxygen production system is specialized for the specific equipment. However, this equipment is similar to the equipment found in other types of activated sludge plants, including air compressors, valves and instruments. Manufacturers commonly aid the operator during start-up with training sessions and field work. A maintenance contract with the supplier can be used to provide the technical services needed. As with any large scale production system, equipment preventive maintenance ensures proper operation and greater efficiency.

QUESTIONS

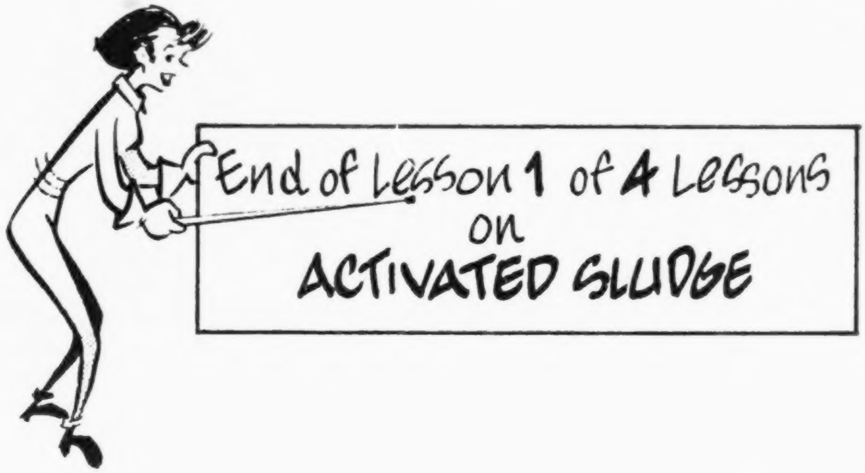
Write your answers in a notebook and then compare your answers with those on page 94.

2.1F What special measures are used to control pure oxygen systems?

2.1G How can hydrocarbons be detected before they reach the reactor?

2.19 Acknowledgment

This section was reviewed by Mr. R.W. Hirsch. The authors thank Mr. Hirsch for his many helpful comments and suggestions.


End of Lesson 1 of 4 Lessons
on
ACTIVATED SLUDGE

Please answer the discussion and review questions before continuing with Lesson 2.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 4 Lessons)

Chapter 2. ACTIVATED SLUDGE

At the end of each lesson in this chapter you will find some discussion and review questions that you should answer before continuing. The purpose of these questions is to indicate to you how well you understand the material in this lesson. Write the answers to these questions in your notebook before continuing.

1. Why does the pure oxygen process normally use covered reactors?
2. How is pure oxygen separated from impurities and other gases in the PSA system?
3. What safety hazards might an operator encounter when working around a pure oxygen system?
4. What safety systems are found around pure oxygen systems to protect operators and equipment?

CHAPTER 2. ACTIVATED SLUDGE

(Lesson 2 of 4 Lessons)

NOTE: The next two lessons, Section 2.2, Return Activated Sludge, and Section 2.3, Waste Activated Sludge, are provided to familiarize you with different ways to control bth the pure oxygen and air activated sludge processes. *YOU,* the operator, will have to determine which ways will work best for your plant. Once a particular procedure is selected, *EVERY OPERATOR ON EVERY SHIFT MUST FOLLOW THE SAME PROCEDURE.* If the procedure does not produce satisfactory results, then new procedures must be developed and tested for everyone to follow.

Abbreviations used in this section include:

1. MLSS, **M**ixed **L**iquor **S**uspended **S**olids, mg/*L*.
2. MLVSS, **M**ixed **L**iquor **V**olatile **S**uspended **S**olids, mg/*L*.
3. RAS, **R**eturn **A**ctivated **S**ludge, mg/*L*.
4. F/M, **F**ood to **M**icroorganism **R**atio, lbs BOD or COD added per day per lb of MLVSS or kg/day per kg MLVSS.
5. Q, Flow, MGD or cu m/sec.

2.2 RETURN ACTIVATED SLUDGE

2.20 Purpose of Returning Activated Sludge

To operate the activated sludge process efficiently, a properly settling mixed liquor must be achieved and maintained. The mixed liquor suspended solids (MLSS) are settled in a clarifier and then returned to the aeration tank as the Return Activated Sludge (RAS) (Fig. 2.6). The RAS makes it possible for the microorganisms to be in the treatment system longer than the flowing wastewater. For conventional activated sludge operations, the RAS flow is generally about 20 to 40 percent of the incoming wastewater flow. *CHANGES IN THE ACTIVATED SLUDGE QUALITY WILL REQUIRE DIFFERENT RAS FLOW RATES DUE TO SETTLING CHARACTERISTICS OF THE SLUDGE.* Table 2.1 shows typical ranges of RAS flow rates for some activated sludge process variations.

TABLE 2.1 A GUIDE TO TYPICAL RAS FLOW RATE PERCENTAGES[a]

Type of Activated Sludge Process	RAS Flow Rate as Percent of Incoming Wastewater Flow to Aeration Tank	
	Minimum	Maximum
Standard Rate	15	75
Carbonaceous Stage of Separate Stage Nitrification	15	75
Step-Feed Aeration	15	75
Contact Stabilization	50	150
Extended Aeration	50	150
Nitrification State of Separate Stage Nitrification	50	200

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[a] *RECOMMENDED STANDARDS FOR SEWAGE WORKS (10 STATE STANDARDS),* Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, 1978 Edition, published by Health Education Service, Post Office Box 7126, Albany, New York 12224. Price, $1.75 plus 48¢ for shipping and handling charges.

2.21 Return Activated Sludge Control

Two basic approaches that can be used to control the RAS flow rate are based on the following:

1. Controlling the RAS flow rate independently from the influent flow; and
2. Controlling the RAS flow rate as a constant percentage of the influent flow.

2.210 Constant RAS Flow Rate Control

Setting the RAS at a constant flow rate that is independent of the aeration tank influent wastewater flow rate results in a continuously changing MLSS concentration. The MLSS will be at a minimum during peak influent flows and at a maximum during low influent flows. This occurs because the MLSS are flowing into the clarifier at a higher rate during peak flow when they are being removed at a constant rate. Similarly, at minimum influent flow rates, the MLSS are returned to the aeration tank at a higher rate than they are flowing into the clarifier. The aeration tank and the secondary clarifier must be looked at as a system in which the MLSS are stored in the aeration tank during minimum wastewater flow and then transferred to the clarifier as the wastewater flows initially increase. In essence, the clarifier has a constantly changing depth of sludge blanket as the MLSS moves from the aeration tank to the clarifier and vice versa. The advantage of using this approach is simplicity, because it minimizes the amount of effort for control. This approach is especially effective for small plants with limited flexibility.

2.211 Constant Percentage RAS Flow Rate Control

The second approach to controlling RAS flow rates requires a programmed method for maintaining a constant percentage of RAS flow to the aeration tank influent wastewater flow rate. The program may consist of an automatic flow-measurement device, a programmed system, or frequent manual adjustments. The programmed method is theoretically designed to keep the MLSS more constant through high and low flow periods.

2.212 Comparison of Both RAS Control Approaches

The advantages of the constant RAS flow approach are the following:

1. Simplicity.
2. Maximum solids loading on the clarifier occurs at the start of peak flow periods.
3. Requires less operational time.

The advantages of the constant percentage RAS flow approach are the following:

1. Variations in the MLSS concentration are reduced and the F/M ratio varies less.
2. The MLSS will remain in the clarifier for shorter time periods which may reduce the possibility of denitrification in the clarifier.

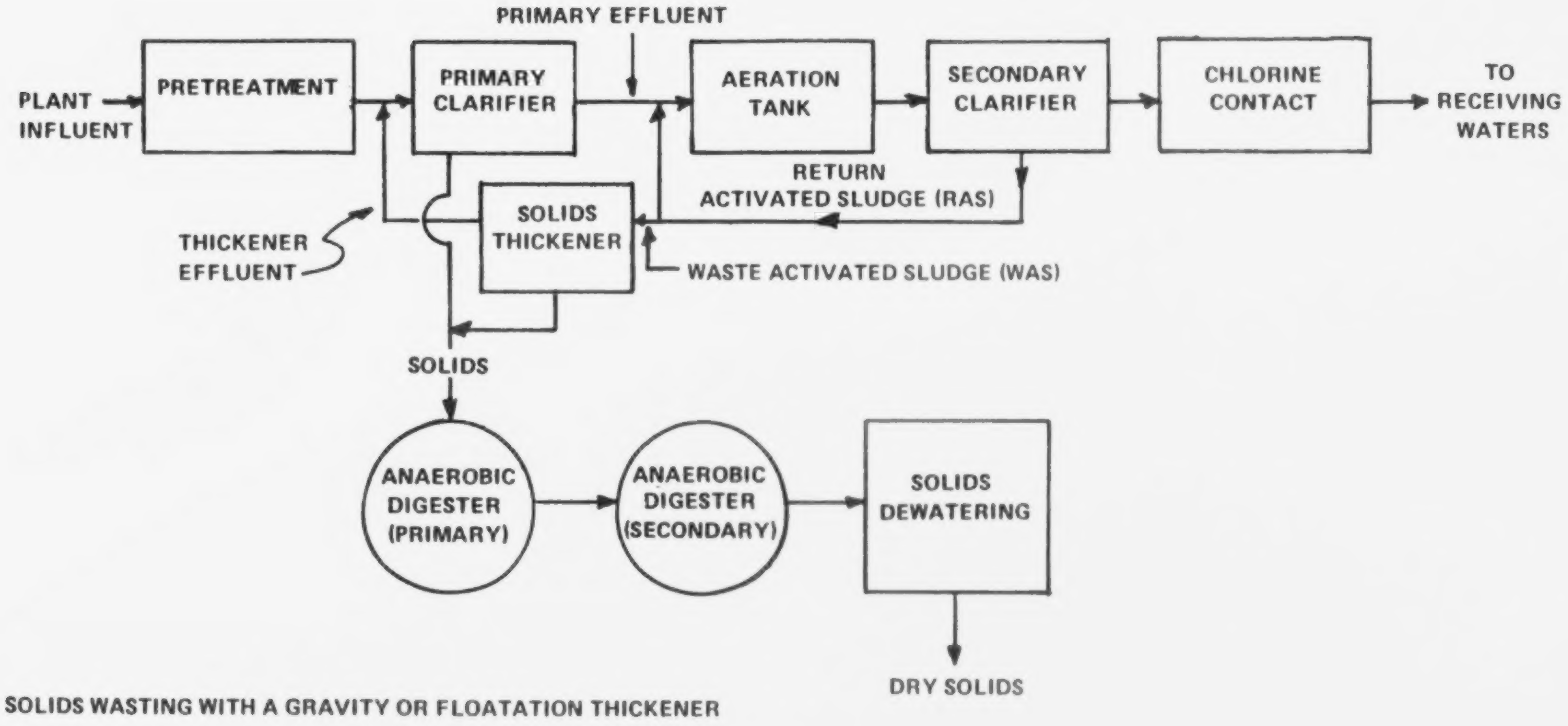

PRIMARY EFFLUENT
PLANT INFLUENT
PRETREATMENT
PRIMARY CLARIFIER
AERATION TANK
SECONDARY CLARIFIER
CHLORINE CONTACT
TO RECEIVING WATERS
RETURN ACTIVATED SLUDGE (RAS)
THICKENER EFFLUENT
SOLIDS THICKENER
WASTE ACTIVATED SLUDGE (WAS)
SOLIDS
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SOLIDS DEWATERING
DRY SOLIDS
SOLIDS WASTING WITH A GRAVITY OR FLOATATION THICKENER

Fig. 2.6 Return and waste activated sludge flow diagram

A limitation of using the constant flow approach is that the F/M ratio is constantly changing. The range of F/M fluctuation due to short-term variations in the MLSS (because of hydraulic loading) is generally small enough so that no significant problems arise.

The most significant limitation of the constant percentage flow approach is that the clarifier is subjected to maximum hydraulic loading when the reactor contains the maximum amount of sludge. This may result in solids washout with the secondary effluent.

In general, it appears that most activated sludge operations perform well and require less attention when the constant RAS flow rate approach is used. In many plants it is much simpler for the operator to let the MLSS fluctuate, as long as adequate treatment can be maintained. Larger, more complex plants may have to vary the RAS to keep the MLSS close to the target value. Activated sludge plants with flows of 10 MGD (37,850 cu m/day) or less often experience large hydraulic surges and performance of these plants will benefit the most from the use of the constant RAS flow rate approach.

Procedures for monitoring and maintaining RAS flow rates are presented in Table 2.2. The operator may develop detailed standard operating procedures for treatment plants by using this table.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 94.

2.2A What words do the letters in the following abbreviations represent?

1. MLSS
2. MLVSS
3. RAS
4. F/M

2.2B What are the two basic approaches that can be used to control the RAS flow rate?

2.22 Methods of RAS Flow Rate Control

For either RAS flow rate control approach discussed above, there are a number of techniques which may be used to set the rate of sludge return flow. The most commonly used techniques are listed below:

1. Monitoring the depth of the sludge blanket.
2. Settleability approach, and
3. SVI approach.

2.220 Sludge Blanket Depth

Monitoring the depth of the sludge blanket in the clarifier is the most direct method available for determining the RAS flow rate. The sludge blanket depth and uniformity may be checked by any of the following methods:

1. A series of air lift pumps mounted within the clarifier at various depths;
2. Gravity flow tubes located at various depths;
3. Electronic sludge level detector (a light source and photoelectric cell attached to a graduated handle or drop cord. The photo-electric cell actuates a buzzer when in contact with the sludge);
4. Sight glass finder (a graduated pipe with a light source and sight glass attached to the lower end);
5. Plexiglass core sampler; and
6. Some type of portable pumping unit with a graduated suction pipe or hose (siphon).

The blanket depth should be kept from one to three feet (0.3 to 1 m) as measured from the clarifier bottom at the sidewall. The operator must check the blanket depth on a routine basis, making adjustments in the RAS to control the blanket depth.

If it is observed that the depth of the sludge blanket is increasing, however, an increase in the RAS flow can only solve the problem on a short-term basis. Increases in sludge blanket depth may result from having too much activated sludge in the treatment system, and/or because of a poorly settling sludge. Long-term corrections must be made that will improve the settling characteristics of the sludge or remove the excess solids from the treatment system. If the sludge is settling poorly, increasing the RAS flow may even cause more problems by further increasing the flow through the clarifier. If the sludge is settling poorly due to bulking, the environmental conditions for the microorganisms must be improved. If there is too much activated sludge in the treatment system, the excess sludge must be wasted.

Measurements of the sludge blanket depth in the clarifier should be made at the same time each day. The best time to make these measurements is during the period of maximum daily flow because the clarifier is operating under the highest solids loading rate. The sludge blanket should be measured daily, and adjustments to the RAS rate can be made as necessary. Adjustments in the RAS flow rate should only be needed occasionally if the activated sludge process is operating properly.

An additional advantage of monitoring the sludge blanket depth is that problems, such as improperly operating sludge collection equipment, will be observed due to irregularities in the blanket depth. A plugged pickup on a clarifier sludge collection system would cause sludge depth to increase in the area of the pickup and decrease in the areas where the properly operating pickups are located. These irregularities in sludge blanket depth are easily monitored by measuring profiles of blanket depth across the clarifier.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 94.

2.2C The sludge blanket depth should be kept to less than what portion or fraction of the clarifier sidewall water depth?

2.2D When should the sludge blanket depth be measured and why?

2.221 Settleability Approach

Another method of calculating the RAS flow rate is based on the results of the 30-minute settling test. Settleability is defined as the percentage of volume occupied by the sludge after settling for 30 minutes. Test is run on a sample collected from the aeration basin effluent.

EXAMPLE

Determine the return activated sludge (RAS) flow as a percentage of the influent flow and in MGD when the influent flow is 7.5 MGD (28,390 cu m/day) and the sludge settling volume (SV) in 60 minutes is 275 ml/*L*.

Known		**Unknown**
Infl. Flow, MGD	= 7.5 MGD	1. RAS Flow as a Percent of Infl. Flow, %
Sl Set Vol. (SV), ml/*L*	= 275 ml/*L*	2. RAS Flow, MGD

TABLE 2.2 STANDARD OPERATING PROCEDURES FOR RAS CONTROL

PROCESS	RAS CONTROL METHOD	MODE OF OPERATION	WHAT TO CHECK	FREQUENCY OF ADJUSTMENT	WHEN TO CHECK	CONDITION	PROBABLE CAUSE	RESPONSE
Complete Mix or Plug Flow	Constant Flow	Manual	Sludge Blanket	Daily	Every 8 Hours	High	Low RAS Rate	Increase Return
						Satisfactory	—	Continued Monitoring
						Low	High RAS Rate	Decrease Return
	Constant % of Influent Flow	Manual	% of Influent Flow	2 Hrs	Every 2 Hrs	High Satisfactory Low	Variations in Daily Influent Flow	Adjust to Desired % of Influent Flow
			Sludge Blanket	Daily	Every 8 Hrs	High	% of Flow Too Low	Increase % of Flow
						Satisfactory	—	Continue Monitoring
						Low	% of Flow Too High	Decrease % of Flow
	Constant % of Influent Flow	Automatic	Sludge Blanket	Daily	Every 8 Hrs	High	% of Flow Too Low	Increase % of Flow
						Satisfactory	—	Continue Monitoring
						Low	% of Flow Too High	Decrease % of Flow
	Control by Sludge Blanket Level	Automatic	Sludge Blanket	Daily	Every 8 Hrs	High or Low	Controller Malfunction	Fix Controller or Manually Adjust Accordingly
						Satisfactory	—	Continue Monitoring
Reaeration or Contact Stabilization	Constant % of Flow	Automatic	Ratio of $MLSS/RAS_{SS}$ (Centrifuge Test)	Every 2 Hrs	Every 2 Hrs	High Ratio	Return Too High	Decrease Return
						Satisfactory	—	Continue Monitoring
						Low Ratio	Return too Low	Increase Return

1. Calculate RAS flow as a % of influent flow.

$$\text{RAS Flow, \%} = \frac{\text{SV, ml}/L \times 100\%}{1{,}000\ \text{ml}/L - \text{SV, ml}/L}$$

$$= \frac{275\ \text{ml}/L \times 100\%}{1{,}000\ \text{ml}/L - 275\ \text{ml}/L}$$

$$= \frac{275\ \text{ml}/L \times 100\%}{725\ \text{ml}/L}$$

$$= 38\%\ \text{of influent flow rate}$$

2. Calculate RAS Flow, MGD.

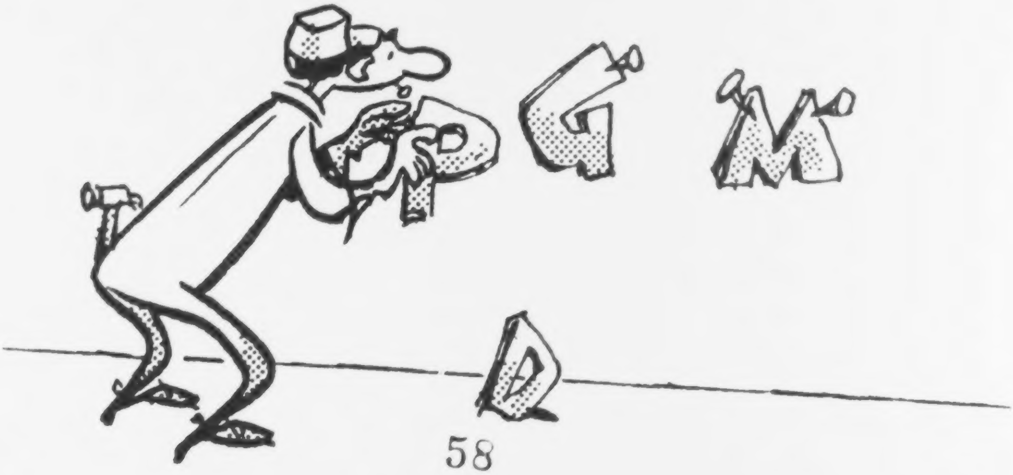
$$\text{RAS Flow, MGD} = \text{RAS Flow, decimal} \times \text{Infl. Flow, MGD}$$

$$= 0.38 \times 7.5\ \text{MGD}$$

$$= 2.8\ \text{MGD} \times 694\ \text{GPM/MGD}^{*}$$

$$= 1{,}945\ \text{GPM}$$

The settleability method assumes that measurements made with a laboratory settling cylinder will accurately reflect the settling in a clarifier. This assumption will seldom (if ever) be true because of the effects of the cylinder walls and the quiescent (still or lack of turbulence) nature of the liquid in the cylinder. Some operators have found that gently stirring (1-2 rpm) the sludge during the settling test reduces these problems.



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* This is a factor for converting MGD to GPM.

Another way to calculate the RAS flow as a percentage of the influent flow is by using the chart in Fig. 2.7 below. First, locate the SV value (from the 60-minute sludge settling test — 275 ml/*L*) on the bottom scale. Draw a vertical line up to the curve and a horizontal line from that point to the left vertical axis. The value (38%) is the RAS flow as a percentage of the influent flow. To find the RAS flow in MGD, multiply the R/Q value (0.38) by Q (7.5 MGD).

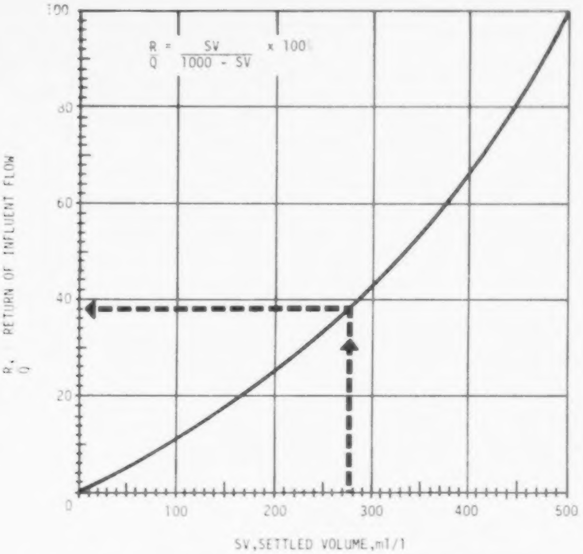

Fig. 2.7 Chart for calculating return sludge flow

2.222 SVI[8] Approach

To determine the RAS flow rate using the Sludge Volume Index (SVI), it is necessary to include the settleability approach. Therefore, this method is subject to the same limitations as the settleability method.

As you can see by the following example, the SVI method uses the Sludge Volume Index to estimate the suspended solids concentration of the return activated sludge (RAS). In calculation #1, RAS Suspended Solids = 8,333 mg/*L*. This value (8,333 mg/*L*) is then used to find the RAS flow rate (calculation #2; 2.4 MGD). Next, the RAS flow as a percentage of influent flow (calculation #3 in the example; 32%)

EXAMPLE

Determine the return activated sludge (RAS) flow in MGD and as a percentage of influent flow when the influent flow is 7.5 MGD (28,390 cu m/day), the mixed liquor suspended solids (MLSS) are 2,000 mg/*L* and the SVI is 120.

Known		Unknown
Infl. Flow, MGD	= 7.5 MGD	1. RAS Flow, MGD
MLSS, mg/*L*	= 2,000 mg/*L*	2. RAS Flow as a percent of Infl. Flow, %
SVI	= 120	

1. Calculate the RAS suspended solids based on the SVI.

$$\text{RAS Susp. Sol., mg}/L = \frac{1{,}000{,}000}{\text{SVI}} = \frac{1{,}000{,}000}{120} = 8{,}333 \text{ mg}/L$$

2. Calculate RAS Flow, MGD, based on SVI.

$$\text{RAS Flow, MGD} = \frac{\text{Infl. Flow, MGD} \times \text{MLSS, mg}/L}{\text{RAS Susp. Sol., mg}/L - \text{MLSS, mg}/L} = \frac{7.5 \text{ MGD} \times 2{,}000 \text{ mg}/L}{8{,}333 \text{ mg}/L - 2{,}000 \text{ mg}/L} = \frac{15{,}000 \text{ MGD} \cdot \text{mg}/L}{6{,}333 \text{ mg}/L} = 2.4 \text{ MGD}$$

3. Calculate the RAS flow as a % of influent flow.

$$\text{RAS Flow, \%} = \frac{\text{RAS Flow, MGD} \times 100\%}{\text{Infl. Flow, MGD}} = \frac{2.4 \text{ MGD} \times 100\%}{7.5 \text{ MGD}} = 32\% \text{ of influent flow}$$

The real value in the SVI is not in calculating the RAS flow, but in its use as a process stability indicator. Changes in the SVI at a constant MLSS are more important than the SVI value. Never be concerned too much about comparing the SVI of different treatment plants because the SVI value that indicates good operation in one plant may not necessarily apply to good operation in other plants. In general, typical pure oxygen activated sludge plants have SVIs from 50 to 100 and air activated sludge plants have SVIs from 100 to 300.

2.23 Return Rates with Separate Sludge Reaeration

In the sludge reaeration (contact stabilization) variation of the activated sludge process, the return sludge rate is much more significant. This is true because the rate of return directly affects the ratio of sludge concentration between the contact portion of the process and the stabilization or re-aeration portion. Generally, a higher rate of return will shift solids from the stabilization portion of the process to the contact portion of the process. Adequate theories for making rational adjustments of the contact/stabilization ratio are just becoming available, and, at this point, the operator must depend on crude rules of thumb or on operating experience to determine which levels are appropriate. These rules of thumb include the following:

1. The suspended solids concentration in the re-aeration portion will eventually equal the RAS suspended solids concentration. Therefore, the RAS flow rate should be controlled on the basis of maintaining the desired suspended solids concentration in the re-aeration portion of the process.

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[8] *Sludge Volume Index (SVI). This test is used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared with its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.*

$$SVI = \frac{\text{Wet Settled Sludge, ml}}{\text{Dried Sludge Solids, mg}} \times 1000$$

TABLE 2.3 EFFECTS OF CHANGES ON RETURN SLUDGE AERATION TIME (RSAT)

PROCESS CONTROL GUIDELINES	CHANGE MADE		EFFECT ON SVI		EFFECT ON NITRIFICATION	
			Increase	Decrease	Increase	Decrease
Step Change	Increase RSAT			•		•
	Decrease RSAT		•		•	
Return Sludge Flow	Increase		•			•
	Decrease			•	•	
Process Air Rate (D.O.)	Increase			•	•	
	Decrease		•			•
Plant Loading lb. COD or BOD per lb. total plant MLVSS	Increase	Increase Plant Q	•			•
		Decrease MCRT				•
	Decrease	Decrease Plant Q		•	•	
		Increase MCRT			•	

NOTE:

1. Changes made in the aeration system are reflected in the secondary clarifiers by how well the sludge settles.
2. When making a process change you must consider what changing one control guideline does to the others.

EXAMPLE: a. An increase in the return sludge flow will decrease the Return Sludge Aeration Time (RSAT).
b. An increase in the process air rate is like increasing the RSAT.
c. An increase in plant Q can result in a return sludge increase.
d. An increase in the return sludge flow can cancel a step change that was made to increase the RSAT.

2. The contact portion suspended solids concentration may be determined by the following formula:

$$\text{Contact MLSS, mg/}L = \frac{\text{RAS Flow, MGD} \times \text{RAS Susp. Sol., mg/}L}{\text{Infl. Flow, MGD} + \text{RAS Flow, MGD}}$$

3. RAS flow may be determined by the following formula:

$$\text{RAS Flow, MGD} = \frac{\text{Infl. Flow, MGD} \times \text{MLSS, mg/}L}{\text{RAS Susp. Sol., mg/}L - \text{MLSS, mg/}L}$$

4. If the SVI remains constant or begins to drop, it indicates that the solids inventory in the process may be too high and wasting should be increased. If the SVI increases in conjunction with a rising sludge blanket in the clarifier, sludge bulking may occur. Refer to Table 2.3 for some suggested solutions under these conditions.

2.24 Acknowledgement

This section was adapted from *PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES,* Municipal Operations Branch, Office of Water Program Operations, Washington, D.C. 20460.

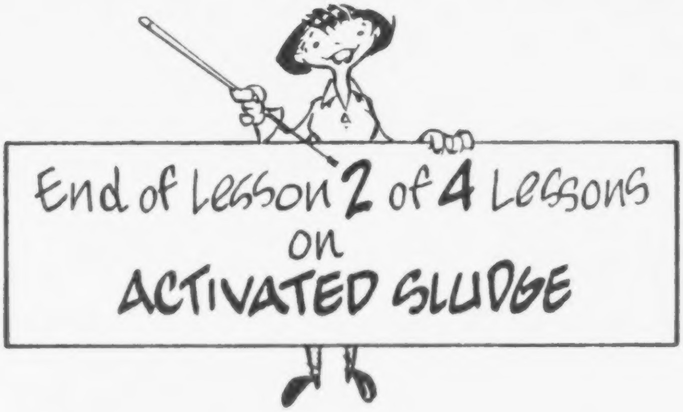
QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 94 and 95.

2.2E What techniques are used to determine the rate of RAS flow?

2.2F How long is the sludge allowed to settle in the settleability test?

2.2G Calculate the return activated sludge (RAS) flow rate in MGD when the influent flow is 4 MGD and the sludge settling volume (SV) in 30 minutes is 250 ml.


End of Lesson 2 of 4 Lessons
on
ACTIVATED SLUDGE

Please answer the discussion and review questions before continuing with Lesson 3.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 4 Lessons)

Chapter 2. ACTIVATED SLUDGE

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

5. What are the advantages of the constant RAS flow approach and the constant percentage RAS flow approach?
6. Different RAS flow rates will be required as the result of what two activated sludge conditions?
7. What is the difference between the method of RAS control and the rate of RAS control?
8. Why is the following statement true and how can this problem be corrected on a long-term basis? If you observe that the depth of the sludge blanket is increasing, an increase in the RAS flow can only solve the problem on a short-term basis.

CHAPTER 2. ACTIVATED SLUDGE

(Lesson 3 of 4 Lessons)

Abbreviations used in this section include:

1. RAS, **R**eturn **A**ctivated **S**ludge
2. WAS, **W**aste **A**ctivated **S**ludge
3. MCRT, **M**ean **C**ell **R**esidence **T**ime
4. MLVSS, **M**ixed **L**iquor **V**olatile **S**uspended **S**olids

2.3 WASTE ACTIVATED SLUDGE

2.30 Purpose of Wasting Activated Sludge

One of the most important controls of the activated sludge process is the amount of activated sludge that is wasted. The amount of waste activated sludge (WAS) removed from the process affects all of the following items:

1. Effluent quality,
2. Growth rate of the microorganisms,
3. Oxygen consumption,
4. Mixed liquor settleability,
5. Nutrient quantities needed,
6. Occurrence of foaming/frothing, and
7. Possibility of nitrifying.

The objective of wasting activated sludge is to maintain a balance between the microorganisms under aeration and the amount of incoming food as measured by the COD or BOD test. When microorganisms remove BOD from wastewater, the amount of activated sludge increases (microorganisms grow and multiply). The rate at which these microorganisms grow is called the growth rate and is defined as the increase in the amount of activated sludge that takes place in one day. The objective of sludge wasting is to remove just the amount of microorganisms that grow in excess of the microorganism death rate. When this is done, the amount of activated sludge formed by the microorganism growth is just balanced by that which is removed from the process. This allows the total amount of activated sludge in the process to remain somewhat constant. This condition is called "steady-state" and is a desirable condition for operation. However, "steady-state" can only be approximated because of the variations in the nature and quantity of the food supply (BOD) and of the microorganism population. The objective of process control is to approach a particular "steady-state" by controlling any one or a combination of the following control guidelines.

1. Sludge Age
2. F/M or Food to Microorganism Ratio
3. MCRT, Mean Cell Residence Time
4. Volatile Solids Inventory
5. MLVSS Concentration

The best mode of process control will produce a high quality effluent which meets NPDES permit requirements with consistent treatment results at a minimal cost.

Wasting of the activated sludge (Fig. 2.6, page 40) is usually achieved by removing a portion of the RAS flow. The waste activated sludge is either pumped to thickening or dewatering facilities and then to a digester or incinerator, or

MLVSS CONCENTRATION

to the primary clarifiers where it is pumped to digester with the raw sludge. Procedures for making WAS adjustments are presented in Table 2.4 which the operator may use to develop standard operating procedures for a treatment plant.

An alternate method for wasting sludge is taking it from the mixed liquor in the aeration tank. There are much higher concentrations of suspended matter in the RAS than there are in the mixed liquor. Therefore, when wasting is practiced from the aeration tank, larger sludge handling facilities are required. Wasting from the RAS takes advantage of the gravity settling and thickening of the sludge that occurs in the secondary clarifier. However, wasting from the aeration tank has the advantage of not wasting excessive amounts of sludge since a large quantity of mixed liquor is involved. The extra security of wasting from the aeration tank should not be underestimated. Unfortunately, many plants do not have the flexibility to waste from the aeration tank nor are there sufficient sludge handling facilities to handle the more dilute sludge.

2.31 Methods of Sludge Wasting

Wasting of the activated sludge can be accomplished on an intermittent or continuous basis. The intermittent wasting of sludge means that wasting is conducted on a batch basis from day to day.

2.310 Sludge Age Control

Sludge age is a measure of the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process. As you can see in this formula for calculating sludge age, it is based on a ratio between the solids in the aeration tank and the solids in the incoming wastewater.

$$\text{Sludge Age, days} = \frac{\text{Suspended Solids Under Aeration, lbs or kg}}{\text{Suspended Solids Added, lbs/day or kg/day}}$$

Using sludge age as a control technique, the operator wastes just enough sludge to maintain the sludge age which produces the best quality effluent. In most activated sludge plants, sludge age ranges from 3 to 8 days. Difficulties are commonly experienced using the sludge age control technique when the BOD or COD to solids ratio in the wastewater changes. This is because sludge age is based on the assumption that the BOD (or COD)/solids ratio is fairly constant. By realizing that the BOD or COD to solids ratio does change and adjusting the sludge age when the ratio changes, the sludge age is a useful process control technique. Calculate the sludge age as shown in the following example.

EXAMPLE

Determine the sludge age for an activated sludge plant with an influent flow of 7.5 MGD (28,390 cu m/day). The primary effluent suspended solids concentration is 100 mg/*L*. Two aeration tanks have a volume of 0.6 MG (2,270 cu m) each and a mixed liquor suspended solids (MLSS) concentration of 2,200 mg/*L*.

Known		**Unknown**
Infl. Flow, MGD	= 7.5 MGD	Sludge Age, days
Prim. Effl. SS, mg/*L*	= 100 mg/*L*	
Tank Vol., MG	= 0.6 MG/tank	
MLSS, mg/*L*	= 2,200 mg/*L*	
No. of tanks	= 2 tanks	

TABLE 2.4 STANDARD OPERATING PROCEDURES FOR WAS CONTROL

METHOD OF CONTROL	PROCESS OPERATION	WHAT TO CHECK	WHEN TO CHECK	CALCULATIONS	FREQUENCY OF ADJUSTMENT	CONDITIONS	PROBABLE CAUSE	RESPONSE[a]
F/M	HIGH RATE	MLVSS & INFLUENT COD	DAILY	F/M BASED ON- $\frac{\text{7 DAY AVG. COD}}{\text{7 DAY AVG. MLVSS}}$	DAILY	ACTUAL F/M: HIGH	EXCESSIVE WASTING	REDUCE WAS
	CONVENTIONAL RATE					SATISFACTORY	—	
	EXTENDED AERATION					LOW	INSUFFICIENT WASTING	INCREASE WAS
MLVSS	HIGH RATE	MLVSS & INFLUENT COD OR BOD	DAILY	VOLATILE SOLIDS INVENTORY	DAILY	ACTUAL MLVSS: HIGH	INSUFFICIENT WASTING	INCREASE WAS
	CONVENTIONAL RATE					SATISFACTORY	—	
	EXTENDED AERATION					LOW	EXCESSIVE WASTING	REDUCE WAS
MCRT	HIGH RATE	MLSS, WAS_{ss}, Q_{was}, & $EFFL_{ss}$	DAILY	7 DAY AVG[b] SOLIDS INVENTORY	DAILY	ACTUAL MCRT: HIGH	INSUFFICIENT WASTING	INCREASE WAS
	CONVENTIONAL RATE			7 DAY AVERAGE[b] OF SOLIDS IN WAS		SATISFACTORY	—	
	EXTENDED AERATION			7 DAY AVERAGE[b] OF SOLIDS IN EFFLUENT		LOW	EXCESSIVE WASTING	REDUCE WAS
SLUDGE AGE	HIGH RATE	INFLUENT SS, & MLSS	DAILY	7 DAY AVG OF SS INVENTORY & SS IN INFLUENT	DAILY	ACTUAL SA: HIGH	INSUFFICIENT WASTING	INCREASE WAS
	CONVENTIONAL RATE					SATISFACTORY	—	
	EXTENDED AERATION					LOW	EXCESSIVE WASTING	REDUCE WAS

[a] **Response - Calculations should be made to determine the WAS rate. However, when increasing or decreasing daily WAS rates, any changes should not exceed 10 to 15 percent of the previous day's WAS rate. This is necessary to allow the process to stabilize.**

[b] **When calculating the MCRT, determine the desired MCRT (7 days) and use the moving average for the number of days (7 days) in the desired MCRT.**

$$\text{Sludge Age, days} = \frac{\text{Solids under aeration, lbs}}{\text{Solids added, lbs/day}}$$

1. Calculate the solids under aeration, lbs.

$$\begin{aligned}\text{Solids under aeration, lbs} &= \underset{\text{Tanks}}{\text{No.}} \times \underset{\text{MG/tank}}{\text{Tank Vol.}} \times \text{MLSS, mg/}L \times 8.34\ \text{lbs/gal}\\ &= 2\ \text{tanks} \times 0.6\ \text{MG/tank} \times 2200\ \text{mg/}L \times 8.34\ \text{lbs/gal}\\ &= 22{,}000\ \text{lbs}\end{aligned}$$

2. Calculate the solids added, lbs/day

$$\begin{aligned}\text{Solids added, lbs/day} &= \text{Infl. Flow, MGD} \times \text{Prim. Effl. SS, mg/}L \times 8.34\ \text{lbs/gal}\\ &= 7.5\ \text{MGD} \times 100\ \text{mg/}L \times 8.34\ \text{lbs/gal}\\ &= 6{,}255\ \text{lbs/day}\end{aligned}$$

3. Determine sludge age, days.

$$\begin{aligned}\text{Sludge Age, days} &= \frac{\text{Solids under aeration, lbs}}{\text{Solids added, lbs/day}}\\ &= \frac{22{,}000\ \text{lbs}}{6{,}255\ \text{lbs/day}}\\ &= 3.5\ \text{days}\end{aligned}$$

Calculate the waste activated sludge (WAS) flow rate using the sludge age control technique as shown in the following example.

EXAMPLE

Determine the waste activated sludge (WAS) flow rate in MGD for an activated sludge plant that adds 6,255 lbs (2,837 kg) of solids per day (from previous problem). The solids under aeration are 33,075 pounds (15,000 kg), the return activated sludge (RAS) suspended solids concentration is 6,300 mg/*L* and the desired sludge age is 5 days. Current sludge waste rate is 4,455 lbs (2,020 kg) per day.

Known		Unknown
Solids Added, lbs/day	= 6,255 lbs/day	WAS Flow, MGD
Solids Aerated, lbs	= 33,075 lbs	
RAS Susp. Sol., mg/*L*	= 6,300 mg/*L*	
Desired Sludge Age, days	= 5 days	
Current WAS Rate, lbs/day	= 4,455 lbs/day	

1. Calculate the desired pounds of solids under aeration (MLSS) for the desired sludge age of 5 days.

$$\begin{aligned}\text{Desired Solids under aeration, lbs} &= \text{Solids Added, lbs/day} \times \text{Sludge Age, days}\\ &= 6{,}255\ \text{lbs/day} \times 5\ \text{days}\\ &= 31{,}275\ \text{lbs}\end{aligned}$$

2. Calculate the additional WAS flow, MGD, to maintain the desired sludge age.

$$\begin{aligned}\text{Additional WAS FLOW, MGD} &= \frac{\text{Solids Aerated, lbs - Desired Solids, lbs}}{\text{RAS Susp. Sol., mg/}L \times 8.34\ \text{lbs/gal}}\\ &= \frac{33{,}075\ \text{lbs} - 31{,}275\ \text{lbs}}{6{,}300\ \text{mg/}L^{*} \times 8.34\ \text{lbs/gal}}\\ &= \frac{1{,}800\ \text{lbs removed per day}^{**}}{52{,}542}\\ &= 0.034\ \text{MGD}^{***} \times 694\ \text{GPM/MGD}\\ &= 24\ \text{GPM}\end{aligned}$$

3. Add the current WAS flow to the additional WAS flow, MGD.

$$\begin{aligned}\text{Total WAS Flow, MGD} &= \text{Current WAS Flow, MGD} + \text{Additional WAS Flow, MGD}\\ &= \frac{\text{Solids Wasted, lbs/day}}{\text{RAS Susp. Sol., mg/}L \times 8.34\ \text{lbs/gal}} + \text{Flow, MGD}\\ &= \frac{4{,}455\ \text{lbs/day}}{6{,}300\ \text{mg/}L \times 8.34\ \text{lbs/gal}} + 0.034\ \text{MGD}\\ &= 0.085\ \text{MGD} + 0.034\ \text{MGD}\\ &= 0.119\ \text{MGD} \times 694\ \text{GPM/MGD}\\ &= 82\ \text{GPM}\end{aligned}$$

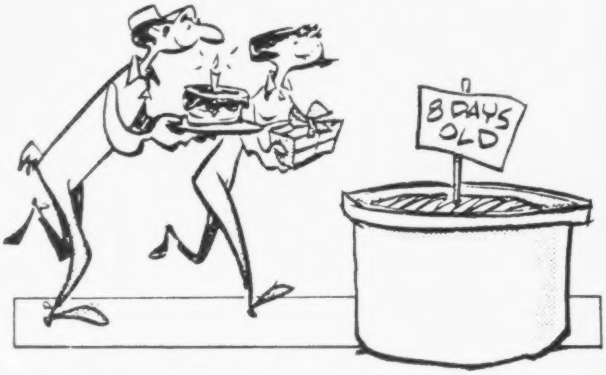
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 95.

2.3A What is the objective of wasting activated sludge?

2.3B How is wasting of the excess activated sludge usually achieved?

2.3C Calculate the waste activated sludge (WAS) flow rate in MGD and GPM for an activated sludge plant that adds 4,750 lbs of solids per day. The solids under aeration are 41,100 pounds and the return activated sludge (RAS) suspended solids concentration is 5,800 mg/*L*. The desired sludge age is 8 days.



2.311 *F/M Control*

F/M control is used to ensure that the activated sludge process is being loaded at a rate that the microorganisms in the mixed liquor volatile suspended solids (MLVSS) are able to use most of the food supply in the wastewater being treated. If too much or too little food is applied for the amount of microorganisms, operating problems may occur and the effluent quality may drop.

There are four facts that should be remembered regarding the F/M method of control:

1. The food concentration is estimated with the COD (or BOD) tests. The oxygen demand tests provide crude but reliable approximations of the actual amount of food removed by the microorganisms.
2. The amount of food (COD or BOD) applied is important to calculate the F/M.
3. The quantity of microorganisms can be represented by the quantity of MLVSS. Ideally, the living or active microorganisms would simply be counted, but this is not feasible, and studies have shown that the MLVSS is a good approximation of the microorganisms concentrations in the MLSS.

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* Remember that mg/*L* is the same as lbs/M lbs.

** Remove an additional 1,800 lbs during a 24-hour period.

*** If the actual solids under aeration are less than the desired solids, reduce your current wasting rate.

4. Operation by or calculations of the F/M should not be on the basis of daily tests because flows and organic concentrations can vary widely on a day-to-day basis. One way to handle these variations is to calculate the F/M based on a seven-day *MOVING AVERAGE*[9] of food (COD, BOD, or TOC), flow and microorganisms (MLSS).

The range of organic loadings of activated sludge plants is described by the F/M. Different ranges of organic loadings are necessary for conventional, extended aeration, and high rate types of activated sludge systems. These ranges have been shown to produce activated sludge that settles well.

Table 2.5 presents the ranges of F/M that have been used successfully with the three loading conditions. The F/M values shown are expressed in terms of BOD, COD, and Total Organic Carbon (TOC). The TOC is an additional means of estimating organic loading. The values indicated are guidelines for process control, and they should not be thought of as minimums or maximums.

TABLE 2.5 TYPICAL RANGES FOR F/M LOADINGS

	Conventional AS Range F/M	Extended Aeration F/M	High-Rate Range F/M
BOD	0.1 to 0.5	0.05 to 0.1	0.5 to 2.5
COD(1)	0.06 to 0.3	0.03 to 0.06	0.3 to 1.5
TOC(2)	0.25 to 1.5	0.1 to 0.25	1.5 to 6.0

(1) Assumes BOD/COD for settled wastewaters = 0.6
(2) Assumes BOD/TOC for settled wastewaters = 2.5

The F/M is calculated from the amount of COD or BOD applied each day and from the solids inventory in the aeration tank.

EXAMPLE

Determine the food to microorganism (F/M) ratio for an activated sludge plant with a COD of 100 mg/*L* applied to the aeration tank, an influent flow of 7.5 MGD (28,390 cu m/day) and 33,075 lbs (15,000 kg) of solids under aeration. Seventy percent of the MLSS are volatile matter. All knowns are seven-day moving averages.

Known		Unknown
Infl. Flow, MGD	= 7.5 MGD	F/M, lbs COD/day/lb MLVSS
COD, mg/*L*	= 100 mg/*L*	
Solids under aeration, lbs	= 33,075 lbs	
MLSS VM, %	= 70%	

1. Calculate the food to microorganism ratio.

$$\text{F/M, } \frac{\text{1 lb COD/day}}{\text{lb MLVSS Solids}} = \frac{\text{Flow, MGD} \times \text{COD, mg/}L \times \text{8.34 lbs/gal}}{\text{Solids under aeration, lbs} \times \text{VM portion}}$$

$$= \frac{\text{7.5 MGD} \times \text{100 mg/}L \times \text{8.34 lbs/gal}}{\text{33,075 lbs} \times 0.70}$$

$$= \frac{\text{6,255 lbs COD/day}}{\text{23,150 lbs MLVSS}}$$

$$= \text{0.27 lbs COD/day/lb MLVSS}$$

The determination of WAS flow rates using F/M control technique is calculated in the same manner as for the sludge age technique. However, the solids inventory for the aeration tank can be more logically determined based on the COD or BOD concentration of the wastewater to be treated when using the F/M for process control. This procedure is shown in the following calculations.

EXAMPLE

Determine the desired waste activated sludge (WAS) flow rate using the F/M control technique. The influent flow is 7.5 MGD (28,390 cu m/day), total aeration tank volume is 1.2 MG (4,542 cu m), COD to aeration tank is 100 mg/*L*, the mixed liquor suspended solids (MLSS) are 3,300 mg/*L* and 70 percent volatile matter, the RAS suspended solids are 6,300 mg/*L* and the desired food to microorganism (F/M) ratio is 0.29. Current WAS flow rate is 0.085 MGD.

Known		Unknown
Infl. Flow, MGD	= 7.5 MGD	WAS Flow, MGD
Tank Vol., MG	= 1.2 MG	
COD, mg/*L*	= 100 mg/*L*	
MLSS, mg/*L*	= 3,300 mg/*L*	
MLSS VM, %	= 70%	
RAS Susp. Sol., mg/*L*	= 6,300 mg/*L*	
Desired F/M, $\frac{\text{lbs COD/day}}{\text{lb MLVSS}}$	$= 0.29\ \frac{\text{lbs COD/day}}{\text{lb MLVSS}}$	
Current WAS, MGD	= 0.085 MGD	

1. Determine COD applied in pounds per day.

$$\text{COD, lbs/day} = \text{Flow, MGD} \times \text{COD, mg/}L \times \text{8.34 lbs/gal}$$

$$= \text{7.5 MGD} \times \text{100 mg/}L \times \text{8.34 lbs/gal}$$

$$= \text{6,255 lbs COD/day}$$

2. Determine the desired pounds of MLVSS.

$$\text{Desired MLVSS, lbs} = \frac{\text{COD applied, lbs/day}}{\text{F/M, lbs COD/day/lb MLVSS}}$$

$$= \frac{\text{6,255 lbs COD/day}}{\text{0.29 lbs COD/day/lb MLVSS}}$$

$$= \text{21,569 lbs MLVSS}$$

3. Determine the desired pounds MLSS.

$$\text{Desired MLSS, lbs} = \frac{\text{Desired MLVSS, lbs}}{\text{MLSS VM portion}}$$

$$= \frac{\text{21,569 lbs}}{0.70}$$

$$= \text{30,813 lbs}$$

4. Determine actual MLSS pounds under aeration.

$$\text{Actual MLSS, lbs} = \text{Tank Vol., MG} \times \text{MLSS, mg/}L \times \text{8.34 lbs/gal}$$

$$= \text{1.2 MG} \times \text{3,300 mg/}L \times \text{8.34 lbs/gal}$$

$$= \text{33,026 lbs}$$

---

[9] *Moving Average. To calculate the moving average for the food for the last 7 days, add up the COD values for the last 7 days and divide by 7. Each day add the most recent day to the sum of values and subtract the oldest value. By using the 7-day moving average, each day of the week is always represented in the calculations.*

5. Calculate the additional WAS flow, MGD, to maintain the desired food to microorganism (F/M) ratio.

$$\begin{aligned}
\text{Additional WAS Flow, MGD} &= \frac{\text{Solids Aerated, lbs - Desired Solids, lbs}}{\text{RAS Susp. Sol., mg/}L \times 8.34\text{ lbs/gal}}\\
&= \frac{33{,}026\text{ lbs} - 30{,}813\text{ lbs}}{6{,}300\text{ mg/}L^{*} \times 8.34\text{ lbs/gal}}\\
&= \frac{2{,}213\text{ lbs removed per day}^{**}}{52{,}542}\\
&= 0.042\text{ MGD}^{***} \times 694\text{ GPM/MGD}\\
&= 29\text{ GPM}
\end{aligned}$$

* Remember that mg/*L* is the same as lbs/M lbs.
** Remove 2,213 lbs during a 24-hour period.
*** If the actual solids under aeration are less than the desired solids, reduce or stop your current wasting rate.

6. Calculate the total WAS flow in MGD and GPM.

$$\begin{aligned}
\text{Total WAS Flow, MGD} &= \text{Current WAS Flow, MGD} + \text{Additional WAS Flow, MGD}\\
&= 0.085\text{ MGD} + 0.042\text{ MGD}\\
&= 0.127\text{ MGD} \times 694\text{ GPM/MGD}\\
&= 88\text{ GPM}
\end{aligned}$$

The F/M control technique for sludge wasting is best used in conjunction with the MCRT control technique. Control to a desired MCRT is achieved by wasting an amount of the aeration tank solids inventory which in turn fixes or provides an F/M ratio.

2.312 MCRT Control

By using the MCRT, the operator can control the organic loading (F/M). In addition, the operator can calculate the amount of activated sludge that should be wasted in a logical manner.

Basically, the MCRT expresses the average time that a microorganism will spend in the activated sludge process. The MCRT value should be selected to provide the best effluent quality. This value should correspond to the F/M loading for which the process is designed. For example, a process designed to operate at conventional F/M loading rates may not produce a high quality effluent if it is operating at a low MCRT because the F/M may be too high for its design. Therefore you must find the best MCRT for your process by relating it to the F/M as well as the effluent COD, BOD, and suspended solids concentrations.

The MCRT also determines the type of microorganisms that predominate in the activated sludge because it has a direct influence on the degree of nitrification which may occur in the process. A plant operated at a longer MCRT of 15 to 20 days will generally produce a nitrified effluent. A plant operating with an MCRT of 5 to 10 days may not produce a nitrified effluent unless wastewater temperatures are unusually high (above 77°F or 25°C). Table 2.6 presents the typical range of MCRT values that will enable nitrification at various wastewater temperatures. MCRTs below the values listed in Table 2.6 are also possible under more optimum conditions, similarly, under less favorable conditions a higher MCRT may be required. The determination of a correct MCRT is only the first of many considerations found in operating an activated sludge plant to achieve nitrification. Nevertheless, the values shown have been used successfully to produce nitrified effluents at numerous plants where ammonia removal is required from the effluent, but not total nitrogen removal.

TABLE 2.6 MCRT NEEDED TO PRODUCE A NITRIFIED EFFLUENT AS RELATED TO THE TEMPERATURE

Temperature, °C	MCRT, Days
10	30
15	20
20	15
25	10
30	7

As stated earlier, MCRT expresses the average time that a microorganism spends in the activated sludge process. The MCRT and the WAS flow rate for maintaining a desired MCRT are shown in the following example.

EXAMPLE

Determine the waste activated sludge (WAS) flow rate using the MCRT technique. The influent flow is 7.5 MGD (28,390 cu m/day), total aeration tank volume is 1.2 MG (4,542 cu m), mixed liquor suspended solids (MLSS) are 3,300 mg/*L*, RAS suspended solids are 6,300 mg/*L*, effluent suspended solids are 15 mg/*L*, and the desired mean cell residence time (MCRT) is 8 days.

Known		Unknown
Infl. Flow, MGD	= 7.5 MGD	WAS Flow, MGD
Tank Vol., MG	= 1.2 MG	
MLSS, mg/*L*	= 3,300 mg/*L*	
RAS SS, mg/*L*	= 6,300 mg/*L*	
Effl. SS, mg/*L*	= 15 mg/*L*	
Desired MCRT, days	= 8 days	

$$\text{MCRT,}^{*}\text{ days} = \frac{\text{Suspended Solids in Aerator, lbs}}{\text{Susp. Sol. Wasted, lbs/day} + \text{Susp. Sol. in Effl., lbs/day}}$$

1. Determine suspended solids in aerator in pounds.

$$\begin{aligned}
\text{SS in Aerator, lbs} &= (\text{Aerator, MG}) \times \text{MLSS, mg/}L \times 8.34\text{ lbs/gal}\\
&= 1.2\text{ MG} \times 3{,}300\text{ mg/}L \times 8.34\text{ lbs/gal}\\
&= 33{,}026\text{ lbs}
\end{aligned}$$

2. Determine suspended solids lost in effluent in pounds per day.

$$\begin{aligned}
\text{SS lost in effl., lbs/day} &= \text{Infl. Flow, MGD} \times \text{Effl. SS, mg/}L \times 8.34\text{ lbs/gal}\\
&= 7.5\text{ MGD} \times 15\text{ mg/}L \times 8.34\text{ lbs/day}\\
&= 938\text{ lbs/day}
\end{aligned}$$

3. Determine the desired suspended solids wasted in pounds per day.

$$\text{MCRT, days} = \frac{\text{SS in Aerator, lbs}}{\text{SS wasted, lbs/day} + \text{SS in Effl., lbs/day}}$$

$$\begin{aligned}
\text{SS Wasted, lbs/day} &= \frac{\text{SS in Aerator, lbs}}{\text{MCRT, days}} - \text{SS in Effl., lbs/day}\\
&= \frac{33{,}026\text{ lbs}}{8\text{ days}} - 938\text{ lbs/day}\\
&= 4{,}128\text{ lbs/day} - 938\text{ lbs/day}\\
&= 3{,}190\text{ lbs/day}
\end{aligned}$$

**NOTE:* Some operators use volatile suspended solids instead of suspended solids.

MCRT may be calculated three different ways:

1. SS in Aerator, lbs,
2. SS in Aerators and Secondary Clarifiers, lbs, and
3. SS in Aerators and Secondary Sludge Blankets, lbs.

4. Determine the waste activated sludge (WAS) flow rate, MGD.

$$\text{SS Wasted, lbs/day} = \text{WAS Flow, MGD} \times \text{RAS SS, mg/}L \times 8.34\text{ lbs/gal}$$

$$\begin{aligned}\text{WAS Flow, MGD} &= \frac{\text{SS Wasted, lbs/day}}{\text{RAS SS, mg/}L \times 8.34\text{ lbs/gal}}\\ &= \frac{3{,}190\text{ lbs/day}}{6{,}300\text{ mg/}L \times 8.34\text{ lbs/gal}}\\ &= 0.06\text{ MGD} \times 694\text{ GPM/MGD}\\ &= 42\text{ GPM}\end{aligned}$$

This means that for the next 8 days, approximately 60,000 gallons per day should be wasted from the RAS system. However, the WAS flow rate should be determined and adjusted daily to maintain the desired MCRT.

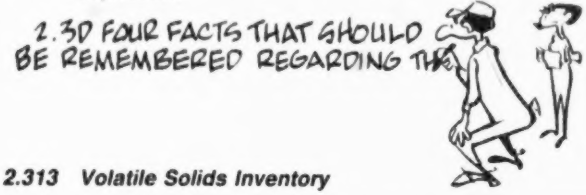
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 95.

2.3D What four facts should be remembered regarding the F/M method of control?

2.3E Calculate the desired pounds of MLSS if the desired F/M ratio is 0.30 lbs COD/day/lb MLVSS if 7,000 lbs of COD per day are added and the volatile matter is 70 percent of the MLSS.

2.3F What does the Mean Cell Residence Time (MCRT) represent?


2.3D FOUR FACTS THAT SHOULD BE REMEMBERED REGARDING THE

2.313 Volatile Solids Inventory

If wasting is done from the RAS, the operator must measure the volatile suspended matter in the RAS to obtain average concentrations. If the volatile content in the RAS suspended solids concentration is decreasing, the WAS flow rate must be increased proportionally to waste the proper amount of volatile suspended solids. Similarly, if there is an increase in the RAS volatile content, the WAS flow rate must be decreased proportionally to avoid losing or wasting too many microorganisms. Using volatile suspended solids values to control the WAS flow will take care of this problem.

When continuous wasting is practiced, the operator should check the RAS volatile suspended solids at least once every shift and make the appropriate WAS flow adjustment.

EXAMPLE

An activated sludge plant is currently wasting 0.05 MGD (35 GPM or 2.18 *L*/sec). The return activated sludge (RAS) volatile suspended solids (VSS) on day 1 are 6,000 mg/*L* and on day 2 (the next day) the RAS VSS are 7,500 mg/*L*. Determine the adjusted waste activated sludge (WAS) rate based on the increase in return activated sludge (RAS) volatile suspended solids (VSS) from 6,000 to 7,500 mg/*L*.

Known		Unknown
WAS Flow, MGD	= 0.05 MGD	Adjusted WAS Flow, MGD
RAS VSS, mg/*L* (day 1)	= 6,000 mg/*L*	
RAS VSS, mg/*L* (day 2)	= 7,500 mg/*L*	

1. Calculate the adjusted waste activated sludge (WAS) flow in MGD and GPM.

$$\begin{aligned}\text{Adj. WAS Flow, MGD} &= \frac{\text{RAS VSS for day 1, mg/}L}{\text{RAS VSS for day 2, mg/}L} \times \text{WAS Flow, MGD}\\ &= \frac{6{,}000\text{ mg/}L \times 0.05\text{ MGD}}{7{,}500\text{ mg/}L}\\ &= 0.04\text{ MGD} \times 694\text{ GPM/MGD}\\ &= 28\text{ GPM}\end{aligned}$$

When intermittent wasting is practiced, the operator must check the RAS volatile suspended solids to calculate the necessary WAS flow. In addition, this calculation must be readjusted for the reduced time of wasting.

EXAMPLE

In the previous example, the waste activated sludge pumping (WAS) period is 4 hours per day and the calculated WAS flow was 0.04 MGD or 28 GPM (1.75 *L*/sec). Calculate the WAS flow.

Known		Unknown
WAS Flow, MGD	= 0.04 MGD	WAS Flow, MGD for 4 hour/day wasting period
Wasting Time, hr/day	= 4 hrs/day	

1. Determine the WAS flow for a 4 hour-day wasting period.

$$\begin{aligned}\text{New WAS flow, MGD} &= \frac{\text{WAS Flow, MGD} \times 24\text{ hr/day}}{4\text{ hours of wasting/day}}\\ &= 0.04\text{ MGD} \times \frac{24\text{ hr/day}}{4\text{ hr/day}}\\ &= 0.24\text{ MGD} \times 694\text{ GPM/MGD}\\ &= 167\text{ GPM}\end{aligned}$$

The operator would repeat the WAS flow calculation for each wasting period to take into account the RAS volatile suspended solids variations.

Intermittent wasting of sludge has the advantage that less variation in the suspended matter concentration will occur during the wasting period, and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are that the sludge handling facilities in the treatment plant may be loaded at a higher hydraulic loading rate and that the activated sludge process is out of balance for a period of time until the microorganisms regrow to replace those wasted over the shorter period of time. Intermittent wasting usually is not practiced in plants treating more than 10 MGD (37,800 cu m/day).

In using either of these methods for wasting, the operator does not have complete control of the amount of activated sludge wasted due to the solids lost in the effluent. This "wasting" of activated sludge in the effluent must be accounted for with any method of process control or the system will always be slightly out of balance. The loss of activated sludge in the effluent generally accounts for less than five percent of the total solids that need to be wasted; however, it is necessary to be aware of this loss and to be able to take it into account by the methods shown in Section 2.312, "MCRT Control." The need for taking into account the solids lost in the effluent is especially important if one encounters situations where large concentrations of suspended solids are washed out in the secondary effluent, as in the case of sludge bulking.

Proper control of the WAS will produce a high quality effluent with mininum operational difficulties.

2.314 MLVSS Control

This technique for process control is used by many operators because it is simple to understand and involves a minimum amount of laboratory control. The MLVSS control technique usually produces good quality effluent as long as the incoming wastewater characteristics are fairly constant with minimal variations in influent flow rates.

With this technique, the operator tries to maintain a constant MLVSS concentration in the aeration tank to treat the incoming wastewater organic load. To put it in simple terms, if it is found that a MLVSS concentration of 2,000 mg/*L* produces a good quality effluent, the operator must waste sludge from the process to maintain that concentration. More sludge is wasted until the desired level is reached again.

The laboratory control tests and operational data involved in using this technique include the following:

1. MLVSS Concentration
2. RAS Volatile Suspended Solids Concentration
3. Influent Wastewater Flow Rate
4. Volume of Aeration Tank

Whether a new plant is being started or the operation of an existing plant is being checked, this control technique is used to indicate when activated sludge should be wasted. In most cases it is not the most reliable technique because it ignores process variables such as F/M and microorganism growth rate necessary for maintaining optimum system balance. When operational problems occur, the operator is unable to make rational process adjustments due to the lack of process control data.

The control technique is implemented by choosing an MLVSS concentration which produces the highest quality effluent while maintaining a stable and economical operation. WAS flow rates are determined as follows:

EXAMPLE

A 1.2 MG (4,542 cu m) aeration tank has a mixed liquor suspended solids (MLSS) concentration of 3,300 mg/*L*. The return activated sludge (RAS) suspended solids concentration is 6,300 mg/*L*. The volatile portion of both suspended solids is 70 percent. Experience has shown that the desired mixed liquor volatile suspended solids (MLVSS) in the aeration tank is approximately 21,250 pounds (9,639 kg). Determine the desired waste activated sludge (WAS) flow rate if the current WAS flow rate is 0.15 MGD.

Known		**Unknown**
Tank Vol., MG	= 1.2 MG	Desired WAS Flow, MGD
MLSS, mg/*L*	= 3,300 mg/*L*	
RAS SS, mg/*L*	= 6,300 mg/*L*	
Volatile Portion	= 0.70	
Desired MLVSS, lbs	= 21,250 lbs	
Current WAS Flow, MGD	= 0.15 MGD	

1. Determine mixed liquor volatile suspended solids (MLVSS) under aeration in pounds.

$$\begin{aligned}\text{Actual MLVSS, lbs} &= \text{Tank Vol., MG} \times \text{MLSS, mg}/L \times \text{Volatile} \times 8.34\ \text{lbs/gal}\\ &= 1.2\ \text{MG} \times 3{,}300\ \text{mg}/L \times 0.70 \times 8.34\ \text{lbs/gal}\\ &= 23{,}120\ \text{lbs}\end{aligned}$$

2. Determine the pounds of volatile solids to be wasted.

$$\begin{aligned}\text{Amt. Wasted, lbs} &= \text{Actual MLVSS, lbs} - \text{Desired MLVSS, lbs}\\ &= 23{,}120\ \text{lbs} - 21{,}250\ \text{lbs}\\ &= 1{,}870\ \text{lbs to be wasted per day}\end{aligned}$$

3. Determine the additional waste activated sludge (WAS) flow rate in MGD and GPM.

$$\text{Amt. Wasted, lbs/day} = \text{WAS Flow, MGD} \times \text{RAS SS, mg}/L \times \text{Vol.} \times 8.34\ \text{lbs/gal}$$

or

$$\begin{aligned}\text{WAS Flow, MGD} &= \frac{\text{Amount Wasted, lbs/day}}{\text{RAS SS, mg}/L \times \text{Volatile} \times 8.34\ \text{lbs/gal}}\\ &= \frac{1{,}870\ \text{lbs/day}}{6{,}300\ \text{mg}/L \times 0.70 \times 8.34\ \text{lbs/gal}}\\ &= 0.05\ \text{MGD} \times 694\ \text{GPM/MGD}\\ &= 35\ \text{GPM}\end{aligned}$$

4. Determine the desired WAS flow rate in MGD and GPM.

$$\begin{aligned}\text{Desired WAS Flow, MGD} &= \text{Current WAS Flow, MGD} + \text{Additional WAS Flow, MGD}\\ &= 0.15\ \text{MGD} + 0.05\ \text{MGD}\\ &= 0.20\ \text{MGD} \times 694\ \text{GPM/MGD}\\ &= 140\ \text{GPM}\end{aligned}$$

2.32 Microscopic Examination

Some operators use a microscope to examine the microorganisms in the mixed liquor for an indication of the condition of the activated sludge treatment process. The majority of the BOD is removed by common zoogleal microorganisms. The microorganisms that are important indicators in the activated sludge process are the *PROTOZOA*[10] and *ROTIFERS*[11]. The protozoa eat the bacteria and help produce a clear effluent. The presence of rotifers is an indication of a stable effluent. If excessive *FILAMENTOUS BACTERIA*[12] are observed, you usually can expect an activated sludge that settles poorly.

If most of the microorganisms in the mixed liquor suspended solids are protozoa (ciliates) and rotifers, you can expect a good settling activated sludge. By using the proper return activated sludge (RAS), waste activated sludge (WAS), and aeration rates, you can produce an effluent with a BOD of less than 10 mg/*L*.

Apparently some filamentous bacteria are good, but too many are bad. Filamentous bacteria can form a network or backbone upon which activated sludge floc can gather and form an excellent settling floc. If the filaments become excessive, a bridging mechanism forms which prevents the activated sludge from flocking or gathering together. If the floc cannot come in contact with each other, sufficient particle mass will not be produced to achieve a good settling floc.

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[10] *Protozoa (pro-toe-ZOE-ah). A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.*

[11] *Rotifers (ROE-ti-fers). Microscopic animals characterized by short hairs on their front end.*

[12] *Filamentous Bacteria (FILL-a-MEN-tus). Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.*

Three groups of protozoa are important to the operator of an activated sludge process.

1. Amoeboids
2. Flagellates
3. Ciliates

AMOEBOIDS (Fig. 2.8)

Look for amoeboids in the mixed liquor suspended solids floc during start-up periods or when the process is recovering from an upset condition.

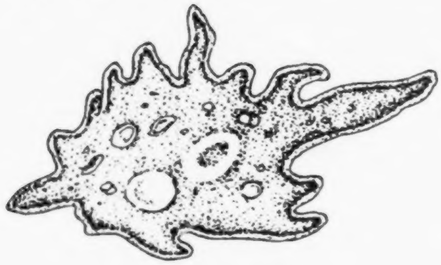


Fig. 2.8 Amoeboids

FLAGELLATES (Fig. 2.9)

Flagellates are usually found with a light, dispersed, straggler floc, a low population of microorganisms, and a high organic (BOD) load. With a high organic (BOD) load, other microorganisms will start to thrive, a more dense sludge floc will develop, and the flagellate population will decrease.

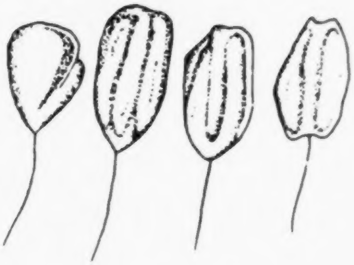


Fig. 2.9 Flagellates

CILIATES

Ciliates are usually found in large numbers when the activated sludge is in a fair to good settling condition. Ciliates are classified into two basic groups, free swimming ciliates (Fig. 2.10) and stalked ciliates (Fig. 2.11).

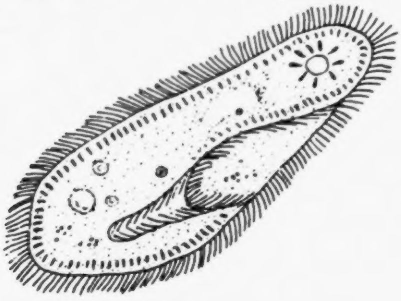


Fig. 2.10 Free swimming ciliates

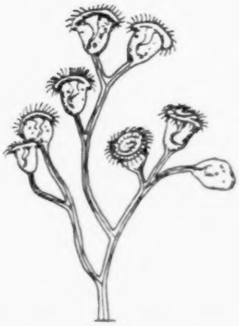


Fig. 2.11 Stalked ciliates

Free swimming ciliates are usually present when there is a large number of bacteria in the activated sludge. These organisms feed on bacteria and help produce a clear effluent. They are associated with a good degree of treatment.

Stalked ciliates are usually present when the free swimming ciliates are unable to compete for the available food. A large number of stalked ciliates and rotifers (Fig. 2.12) will indicate a stable and efficiently operating activated sludge process.

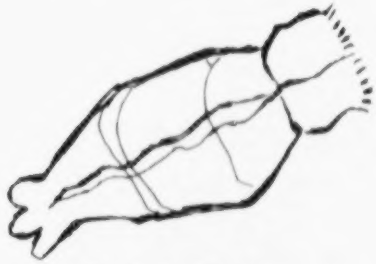


Fig. 2.12 Rotifers

The types of microorganisms and the numbers of microorganisms can be used as a guide in making activated sludge process control adjustments. Figure 2.13 can help you determine whether the mean cell residence time (MCRT) should be increased or decreased. A decline in microorganisms, especially ciliates, is frequently a warning of a poorly settling sludge. If a relatively large number of amoeboids and flagellates are observed, try increasing the MCRT. If the numbers of microorganisms are relatively low with rotifers predominating and you have a pin floc, try decreasing the MCRT.

These observations can allow an operator to detect a change in organic loading or in level of a toxic chemical before the activated sludge process becomes upset. The changes in type and number of microorganisms should be compared with observations of the settling characteristics of the mixed liquor suspended solids in the 30-minute settleability test and with the calculated food to microorganism ratio.

In summary, large numbers of ciliates and rotifers are an indication of a stable activated sludge process that will produce a high quality effluent.

Major portions of this section were taken from *PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES*, Municipal Operations Branch, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington, D. C. 20460.

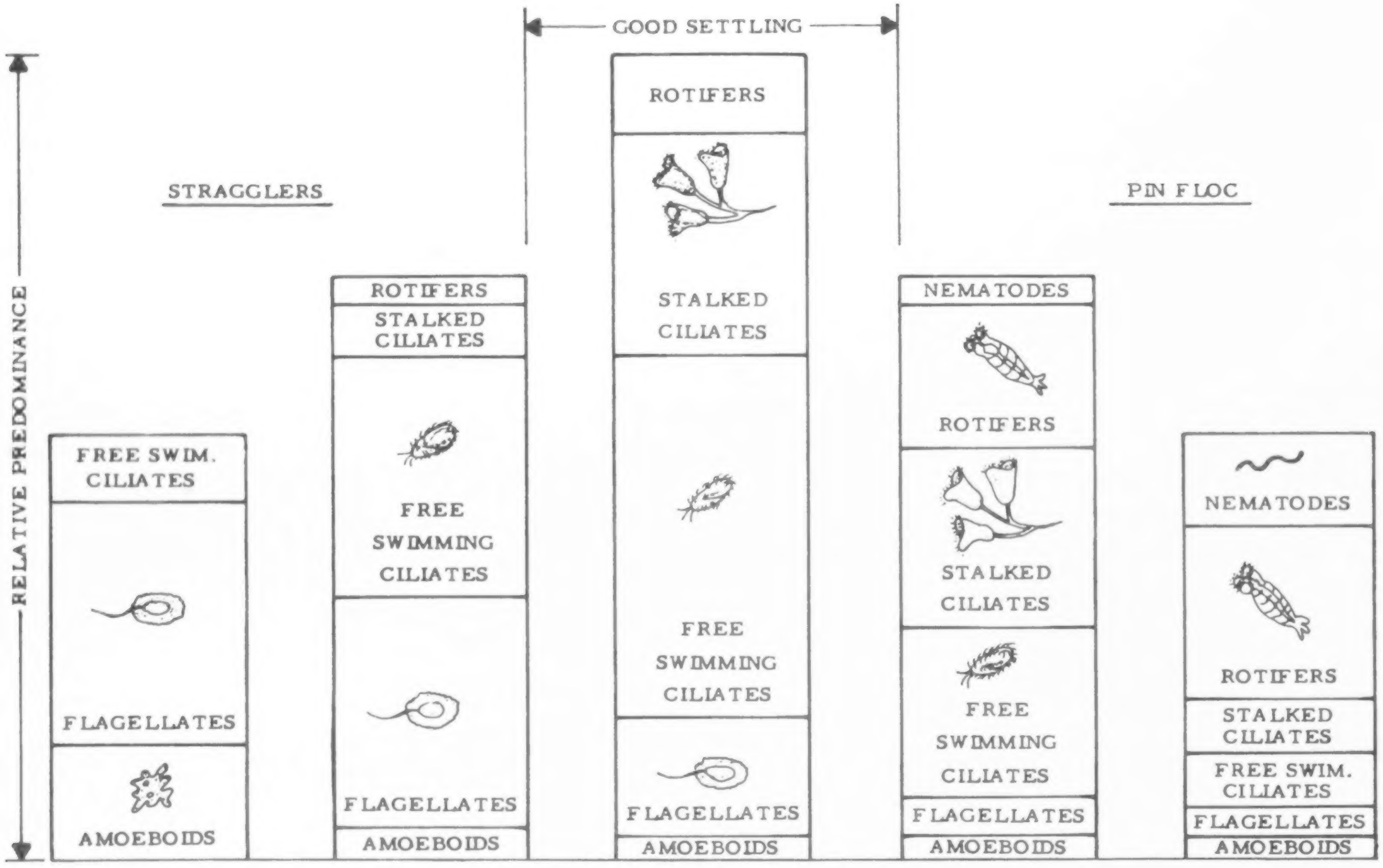

GOOD SETTLING
STRAGGLERS
PIN FLOC
RELATIVE PREDOMINANCE
FREE SWIM. CILIATES
FLAGELLATES
AMOEBOIDS
ROTIFERS
STALKED CILIATES
FREE SWIMMING CILIATES
FLAGELLATES
AMOEBOIDS
ROTIFERS
STALKED CILIATES
FREE SWIMMING CILIATES
FLAGELLATES
AMOEBOIDS
NEMATODES
ROTIFERS
STALKED CILIATES
FREE SWIMMING CILIATES
FLAGELLATES
AMOEBOIDS
NEMATODES
ROTIFERS
STALKED CILIATES
FREE SWIM. CILIATES
FLAGELLATES
AMOEBOIDS

Fig. 2.13 Relative number of microorganisms vs. sludge quality

2.33 The Al West Method

Section 2.2, "Return Activated Sludge" and 2.3, "Waste Activated Sludge" have outlined various methods operators used to "control" their activated sludge process. Mr. West has correctly observed that the activated sludge "process is *NOT* controlled by attempting to achieve *PRECONCEIVED* levels of *INDIVIDUAL* variables such as mixed liquor sludge concentration, mean cell residence time and food to microorganism ratios. *CONTROL* tests such as final clarifier sludge blanket depth determinations, mixed liquor and return sludge concentrations (by centrifuge) and sludge settleability are used to define sludge quality and process status and to determine process adjustments." Mr. West worked continuously to develop better ways for operators to control the activated sludge process.

2.34 Summary on RAS and WAS Rates

How should you operate your activated sludge process? Only you can answer this question. In Chapters 8 and 11 of Volumes I and II of *OPERATION OF WASTEWATER TREATMENT PLANTS,* we outlined what we consider are simple and direct procedures for operating package plants, oxidation ditches and conventional activated sludge plants. In Chapter 2 of this manual, various alternative methods were outlined on how to control the activated sludge process.

What counts is the effluent quality from your activated sludge plant. The effluent quality is influenced by influent characteristics and conditions in the aeration tank and secondary clarifier. Observe these characteristics and conditions; you must be alert for any change and make appropriate adjustments to control the activated sludge process. *EVERY OPERATOR ON EVERY SHIFT MUST FOLLOW THE SAME PROCEDURES. TRY NOT TO ADJUST YOUR RAS AND WAS RATES BY MORE THAN 10 OR 15 PERCENT FROM ONE DAY TO THE NEXT DAY. SELECT A METHOD YOU UNDERSTAND, RECORD AND ANALYZE DATA, STICK WITH YOUR METHOD AND YOU CAN MAKE IT WORK TO PRODUCE A GOOD EFFLUENT.*

2.35 Acknowledgment

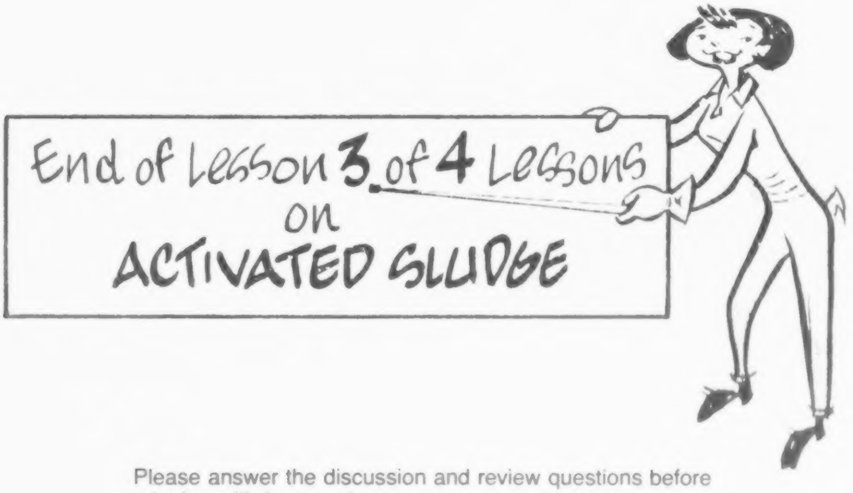
Major portions of Section 2.3 were adapted from *PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES,* Municipal Operations Branch, Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C. 20460.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 95.

2.3G Which microorganisms are important indicators in the activated sludge process?

2.3H In the Al West method, what important activated sludge control tests are used to define sludge quality and process status?


End of Lesson 3 of 4 Lessons
on
ACTIVATED SLUDGE

Please answer the discussion and review questions before continuing with Lesson 4.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 4 Lessons)

Chapter 2. ACTIVATED SLUDGE

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

9. What items are affected by the amount of waste activated sludge (WAS) removed from the process?
10. How will you know when you have established the best mode of process control for your plant?
11. What is the basis for the F/M method of controlling the activated sludge process?
12. How would you adjust the MCRT to produce a nitrified effluent?
13. What are the advantages and limitations of intermittent wasting of activated sludge?
14. How would you select the RAS and WAS rates for your activated sludge plant?

CHAPTER 2. ACTIVATED SLUDGE

(Lesson 4 of 4 Lessons)

2.4 TREATMENT OF BOTH MUNICIPAL AND INDUSTRIAL WASTES

2.40 Monitoring Industrial Waste Discharges (Also see Chapter 5, "Industrial Waste Monitoring.")

Industrial manufacturing processes of most types generate some waste materials. These waste materials take the form of liquid, gaseous or solid residuals. In most cases, the deliberate and indiscriminate disposal of these waste materials to the collection system will have a deteriorating effect upon the activated sludge process and possible detrimental effects on the treatment plant effluent receiving waters.

As discussed in Chapter 11, Section 11.011, you should become acquainted with the various industrial facilities in your area to determine what, if any, adverse impact they may create on your activated sludge process.

2.400 Establishing a Monitoring System

Regulations at both state and federal levels usually require that industrial waste monitoring be established as an important part of an industrial waste control and treatment system.

An industrial waste monitoring program is valuable for the following reasons:

1. To assure regulatory agencies of industrial compliance with discharge requirements and implementation schedules set forth in the discharge permit,
2. To maintain sufficient control of treatment plant operations to prevent NPDES permit violations, and
3. To gather necessary data for the future design and operation of the treatment plant.

In establishing a monitoring program, one of the first tasks should be an examination of the wastewater characteristics of each industry that discharges to the collection system. Awareness of the specific types of harmful waste materials that may enter the collection system will help you prepare a monitoring program to protect the treatment plant and receiving waters.

Some industries pretreat wastewaters before discharge to the collection system to recover valuable materials, to reduce sewer-service charges, and to keep undesirable constituents out of the sewers and treatment plant. However, if undesirable constituents are known to be present in the municipal wastewater stream, pretreatment of the industrial wastewater portion must be enforced to reduce the constituents to acceptable levels. Proper monitoring at the site of an industrial wastewater pretreatment plant is essential. Additionally, if it is likely that an accidental spill or unlawful discharge may escape pretreatment and enter the collection system, a sophisticated monitoring system should be installed at your treatment plant. The reasons for wastewater monitoring at the treatment plant itself include establishing a last point of measurement of certain problem constituents before entering the unit processes so that the operator can start corrective operational measures where possible.

2.401 Automatic Monitoring Units

Automatic monitoring of several wastewater characteristics has been a dependable method of alerting the operator to abnormal influent wastewater conditions. Numerous water quality indicators are used for operational controls, yet the number of water quality indicators that can be automatically measured without difficulty is limited. Therefore, it is essential that the operator also rely on the appearance and odor of the influent wastewater as part of the monitoring program at the treatment plant.

Some of the more common monitoring devices include:

1. Flow measuring,
2. pH monitoring,
3. Oxidation potential monitoring (conductivity),
4. Suspended solids monitoring,
5. DO monitoring,
6. Wastewater samplers, and
7. Gas-phase hydrocarbon analyzer.

Normally, data is recorded on a strip chart recorder; however, other equipment, such as pumps or valves may be activated by these monitoring devices. The monitoring systems should also be combined with an alarm system that will give the operator warning when a high concentration of an undesirable water quality indicator reaches the monitoring station.

2.41 Common Industrial Wastes

Reduction and/or elimination of harmful waste constituents from industrial discharges may be controlled by enforcing your municipal sewer ordinance. Several objectionable industrial waste constituents and the possible effects of each waste are discussed below.

1. Flammable Oils. Examples of flammable oils are crude gasoline, benzene, naphtha, fuel oil, and mineral oil. These substances are not soluble and tend to collect in pools, thus creating potential explosive conditions. When methane gas is mixed with flammable oils, a very powerful explosion may result.
2. Toxic Gases. Toxic gases such as hydrogen sulfide (H_2S), methane (CH_4), and hydrogen cyanide (HCN) are often present or may be formed in industrial discharges. Wastewater with high quantities of sulfate can cause problems in anaerobic decomposition, due to the formation of H_2S. Also, cyanide combines with acid wastes to form the extremely toxic gas, HCN.
3. Oils and Greases. A municipal plant generally does not have facilities for the removal of significant quantities of oils and grease. Pretreatment of wastewater may be desirable to reduce the total concentration of oils and grease (hexane extractables). In general, emulsified oils and greases of vegetable and animal origin are biodegradable and can be successfully treated by a properly designed municipal treatment facility. However, oils and greases of mineral origin may cause problems and these are the constituents generally requiring pretreatment.
4. Settleable Solids. Settleable solids cause obstructions in the sewer system by settling and accumulating. At places where wastewater accumulates, anaerobic decomposition may take place, producing undesirable products, such as hydrogen sulfide and methane.

   High settleable solids concentrations may overload the capacity of the treatment plant.
5. Acids or Alkalies. Acids or alkalies are both corrosive and may also interfere with biological treatment. Even neutral sulfate salts may cause corrosion, since the sulfate can be biologically reduced to sulfide and then oxidized to sulfuric acid.
6. Heavy Metals. Heavy metals may be toxic to biological treatment systems or to aquatic life in the receiving water and may adversely affect downstream potable water supplies.
7. Cyanides. Cyanides are toxic to bacteria and may cause hazardous gases in the sewer.
8. Organic Toxicants. Pesticides and other extremely toxic substances in wastewater are objectionable except in very small concentrations. Even if the biological treatment systems are not altered by higher concentrations, toxicants may still damage receiving surface water quality.

2.42 Effects of Industrial Wastes on the Treatment Plant Unit Processes

When undesirable industrial constituents enter the municipal waste stream, certain adverse effects on common unit treatment processes can be expected. For example, acids and corrosive materials would damage the conveyance system of pipes and pumps. Dangerous gases and explosive materials create hazards to plant personnel. Other constituents, such as heavy metals or toxic organics, may actually inhibit or kill the microorganisms at the treatment plant.

Some of the more common adverse effects that industrial waste constituents have on unit processes are listed below.

A. Sewer System

   1. Corrosion caused by acids
   2. Clogging due to fats and waxes
   3. Hydraulic overload by discharge of cooling waters
   4. Potential explosion danger with gasolines and other fuels

B. Grit Channels
   1. Overloading with high grit concentrations
   2. Increased organic content of grit
   3. Intermittent flow reduces removal efficiency

C. Screens and Comminutors
   1. Overload with excess solids
   2. Excessive wear on comminutor cutting surfaces by hard materials

D. Clarifiers
   1. Fluctuating hydraulic loadings reduce removal efficiencies
   2. Scum problems from excessive quantities of oils
   3. Impaired effluent quality caused by finely divided suspended solids
   4. Excessive sludge quantities with high suspended solids concentrations

E. Sludge Digesters
   1. Negative effects on sludge digestion caused by inorganic solids
   2. Overload caused by excessive solids
   3. Increased scum layers caused by excessive organic solids
   4. pH problems from an industrial wastewater with a high sugar content
   5. Toxicants

F. Activated Sludge
   1. Deterioration in quality with transient loading
   2. Excessive carbohydrate concentrations can cause bulking or poorly settling sludge
   3. Toxicants
   4. Foaming problems

2.43 Operational Strategy

2.430 Need for a Strategy

Adverse effects to the activated sludge process can be significantly reduced if the operator has a plan of operation or an operational strategy ready to implement when adverse industrial constituents enter the treatment plant.

This section will discuss the observations and corrective actions (operational strategy) taken at a typical activated sludge plant when (1) a toxic waste (cyanide), and (2) a high BOD waste (milk) enter the treatment plant mixed with the domestic wastewater.

This typical plant monitors the influent pH and the aeration tank DO. These are the only two water quality indicators that are monitored continuously. The operators at this plant rely heavily on sight and smell observations of the influent wastewater, aeration tank mixed liquor, and the secondary effluent as the first indicators of shock or overload conditions at the plant. These observations allow the proper corrective actions to be implemented before significant damage to the activated sludge process occurs.

Our typical treatment plant is designed to operate in the contact stabilization modification of the activated sludge process. This mode of operation is very desirable when industrial waste constituents that are harmful to the organisms in activated sludge may occur unexpectedly in the treatment plant influent. The advantage of operating in this mode is discussed in Chapter 11, Section 11.91.

The average operating data for our typical plant is as follows:

Peak influent flow : 17.0 MGD
Raw wastewater COD : 400 to 450 mg/*L*
Primary effluent feed to the aeration tanks : Three-point step feed
Aeration contact basin F/M : 0.5 to 0.8 lbs COD/day/lb MLVSS
DO through the system : 0.05 to 5.0 mg/*L*
Sludge aeration time : 7 to 12 hours to keep most of the biomass under aeration
Ammonia oxidation : 30 to 50 percent
Secondary effluent nitrate : 0.3 to 1.5 mg/*L*
Secondary effluent SS : 5 to 10 mg/*L* (varies with the waste)
Air-to-flow ratio : 1.8 to 2.5 cu ft/gal
RAS flow rate control : Flow paced and allow "zero" sludge blanket in the secondary clarifier

2.431 Recognition of a Toxic Waste Load

In our sample plant, the first indication of a toxic waste load within the treatment plant is recognized by observing the aeration basin DO recording device. As the toxic load moves into and through the aeration basin, the DO residual will increase significantly. A DO increase without an air input increase indicates that the toxic waste load is killing the microorganisms in the aeration tank, thus reducing the oxygen uptake (respiration) by the microorganisms.

A second indication of a toxic waste reaching the plant may be observed in the secondary clarifier effluent. The effluent will begin to exhibit floc carry-over (an indication of cell death). The degree of carry-over will depend on the substance and quantity of the toxic waste.

When a toxic substance is known to have entered the treatment plant, the operator should make every effort to obtain a sample of the wastewater and have the sample analyzed as soon as possible to determine the toxic constituents. A record of these upset conditions and the constituents involved is very important so that if uncontrollable problems develop at the treatment plant, the records can be reviewed in an attempt to determine the input source.

2.432 Operational Strategy for Toxic Wastes

The operator's primary mission in the case of toxic wastes is to save the activated sludge system.

When the operator in our sample plant recognizes a toxic waste condition, the RAS flow is reduced significantly to keep as many of the bacteria affected by the toxic waste in the secondary clarifiers. The operator then significantly increases the WAS flow to purge the activated sludge process of the toxic waste and the sick or dead microorganisms. Additionally, every attempt is made to process the toxic waste flow through the plant as fast as possible to reduce contamination of other unit processes such as anaerobic or aerobic digesters.

The toxic waste processing time through our typical plant may vary from 30 minutes to 2 hours.

2.433 Recognition of a High Organic Waste Load

The first indication of a high organic waste load within the treatment plant is recognized by observing the aeration basin DO recording device. As the high organic load moves into and through the aeration basin, the DO residual will decrease significantly. A DO decrease without an air input decrease indicates that the high organic waste load is too great for the available microorganisms to properly assimilate and metabolize the waste (food to microorganism ratio is out of balance because of a greater BOD (food)).

If the high organic waste load is significant, the nutrient content of the municipal waste may be inadequate for proper biological activity. Therefore, nitrogen and phosphorus can be added on the basis of a total carbon measurement of the influent wastestream to ensure adequate amounts of these nutrients.

The quantity of nitrogen and phosphorus required for a waste can be estimated from the quantity of sludge produced per day. The pounds of nitrogen required per day will be about 10 percent of the volatile solids (dry weight) produced each day. The phosphorus requirement will be one-fifth of the nitrogen requirement. The amounts of nitrogen and phosphorus added daily are equal to the differences between the quantity required and the quantity in the wastes.

$$\text{Additional Nitrogen, lbs/day} = \text{Nitrogen Required, lbs/day} - \text{Nitrogen in Wastes, lbs/day}$$

A second indication of high organic waste reaching the plant may be observed in the secondary clarifier effluent. The effluent will become more turbid (less clear) indicating that the waste flow has not been adequately treated.

The sampling and analysis recommended in Section 21.401 should also be implemented in this situation.

2.434 Operational Strategy for High Organic Waste Loads

The operator's primary mission in the case of high organic loads is to improve the microorganism treatment efficiency.

Upon recognizing a high organic waste load condition, the RAS flow must be significantly increased to provide more microorganisms to the aeration contact basin to adequately treat the high organic waste. The rate of RAS increase must be accomplished gradually so that both design hydraulic and solids loading rates for the secondary clarifiers are not exceeded.

In addition, every attempt should be made to increase the air or oxygen input to maintain proper DO levels in the aeration basins. If appropriate, nitrogen and phosphorus should be added to provide the additional nutrients needed by the microorganisms.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 95.

2.4A Why is an industrial waste monitoring program valuable for the operator of an activated sludge plant?

2.4B List five common wastewater monitoring devices.

2.4C What would you do if a high organic waste load entered your activated sludge plant?

2.5 INDUSTRIAL WASTE TREATMENT

2.50 Need to Treat Industrial Wastes

As the operator of an industrial wastewater treatment plant, it is your responsibility to ensure that required sewer-use standards or effluent quality standards are achieved in order that the production system may remain on-line. Because of tighter restrictions on the quality of industrial wastewater that can be discharged to municipal sewer systems or receiving streams, your industrial facility may be required to pretreat the industrial process wastewaters. This pretreatment can be costly, but failure to properly pretreat these wastewaters may result in excessive sewer use fees and treatment charges, in severe fines for violations and possible production shutdowns. Many industries are finding it more economical to build, operate and maintain their own treatment facilities than to pay for pretreatment and use of municipal treatment plants.

This section will provide you with information necessary to increase your process awareness and alert you to precautions required in operating your activated sludge industrial wastewater treatment plant.

Although there is a wide variety of applications of the activated sludge process to industrial wastewater treatment in operation today, this section will concentrate on some typical plants which treat wastes from fruit and vegetable processing, paper product manufacturing, and petroleum refining.

2.51 Characterization of Influent Wastes

The character of the wastewater is dependent on the particular production process and the way it is operated. The first step to successful operation of your treatment plant is to characterize the wastewaters through various analyses. These characteristics describe the concentrations or amounts of wastes in the wastewaters and include BOD, total suspended solids, settleable solids, COD, pH, DO, temperature, total solids, dissolved solids, chloride, nitrogen, and phosphorus. These pollutants are often used to determine the fees paid by industry for use of municipal collection systems and treatment plants. Other pollutants that are measured included toxic substances such as arsenic, zinc and copper. Toxic substances usually must be pretreated by industry. The procedures for measuring the concentrations or amounts of these wastes are outlined in Chapter 16, "Laboratory Procedures and Chemistry," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS.*

Another important characteristic of the wastewater being treated is the flow. Flow rate should be described in terms of the daily average and also the fluctuations. Because many industrial facilities do not generate consistent waste flows and constituents over a 24-hour day or 7-day week, you must determine when the variations can be expected and operate your activated sludge process in a manner that anticipates these variables and does not allow these fluctuations to cause a deterioration of the quality of the plant effluent. Effective sewer-use ordinances require that industry notify the operator of a municipal treatment plant whenever a significant accidental discharge (spill or dump) or process failure might upset a treatment plant. By warning the operator of the volume and nature of the discharge, provisions can be made to handle the waste when it reaches the plant. Process supervisors should notify the operators of their industrial wastewater treatment plants when a potentially harmful spill or dump occurs.

2.52 Common Industrial Wastewater Variables

2.520 Flow

Flow measurements are a basic requirement at every treatment plant. Recorded flow data are essential because these records allow you to establish correct operating guidelines (loadings) and determine if your treatment plant is properly sized to process the hydraulic loads.

In many industrial production facilities, the wastewater flows are generally higher during the day-shift hours of Monday through Friday. Significant flow reductions may be anticipated in the evening hours with possible "zero" flow conditions during weekends, holidays, and annual production maintenance shutdown periods.

In cases where flows to your treatment plant approach or exceed the hydraulic design capacity, every effort should be taken to implement a production facility pollution abatement program to reduce water consumption and minimize waste generation through proper management of processing and production operations.

2.521 pH

The pH of production facility wastewaters may vary from 2.5 to 13.0 depending upon the production being processed and the type of operations conducted within the facility. Natural waters generally have pH values between 6.5 and 8.0.

If the wastewater pH varies greatly from neutral (7.0), the wastewater should be adjusted (neutralized). Neutralization may be accomplished in a tank of sufficient detention time (15-20 minutes). Sulfuric acid (to lower pH) or caustic (to increase pH) addition to the waste stream may be controlled with pH probes and controllers for rough and fine pH adjustment.

2.522 BOD and Suspended Solids

The BOD test is the rate of oxygen uptake from the wastewater by microorganisms in biochemical reactions. These microorganisms are converting the waste materials to carbon dioxide, water and inorganic nitrogen compounds. The oxygen demand is related to the rate of increase in microorganism activity resulting from the presence of food (organic wastes) and nutrients. Microorganism activity may be hindered in some industrial wastes due to the presence of toxic wastes. Industrial wastewaters may contain levels of BOD from 500 to 10,000 mg/*L*.

Suspended solids information may be used to determine the quantity of solids which will require removal in the activated sludge treatment system. Typical suspended solids concentrations for industrial wastewaters vary from 125 mg/*L* to 3,000 mg/*L*.

For any waste, the concentrations of pollutants can be readily reduced by simply using more water, but the increase in volume will result in the same number of total pounds of pollutants. The organic load, consisting of both BOD and suspended solids, can only be effectively reduced by reductions in pounds of pollutants generated at production facility sources.

2.523 COD

Chemical oxygen demand (COD) is an alternative to biochemical oxygen demand (BOD) for measuring the pollutional strength of wastewaters. When considering the use of COD for measuring the strength of wastewater, you must bear in mind that the BOD and COD tests involve separate and distinct reactions. Chemical oxidation measures the presence of carbon and hydrogen, but not amino nitrogen in organic materials. Furthermore, the COD test does not differentiate between biologically stable and unstable compounds. For example, cellulose is measured by chemical oxidation, but is not measured biochemically under aerobic conditions.

The primary disadvantage of the COD test is its susceptibility to interference by chloride. Thus, wastewaters containing *HIGH* salt concentrations, such as brine, cannot be readily analyzed without modification.

2.524 Nutrients

Aside from carbonaceous organic matter (which is measured largely as BOD), the nutrients required for reproduction of microorganisms are nitrogen (N) and phosphorus (P). In unusual cases, other elements may also be critical. These other essential nutrients include iron, calcium, magnesium, potassium, cobalt, and molybdenum. Since many production facility wastewaters are deficient in nutrients for biological treatment, nutrients can be added to optimize your biological wastewater treatment system efficiency.

The amount of these nutrients required for a treatment process depends both on the age of the microorganisms and the numbers of cells generated (growth rate) during the reduction of BOD. A BOD/nitrogen/phosphorus ratio of 100:5:1 is usually adequate. However, high-rate systems with no available nitrogen or phosphorus in the wastewater may require a ratio of 100:10:2. Ratios lower than 100:5:1 may be adequate for aerated ponds and systems with a very long sludge age. All nutrients need to be in a soluble form to be used by the microorganisms.

2.525 Toxicity

The most common causes of wastewater toxicity are excessive amounts of free ammonia, residual chlorine, detergents, paints, solvents, and biocides. Other wastes that can upset microorganisms include heavy metals, chlorinated hydrocarbons, petroleum products, acids, bases (caustics) and temperature changes. These toxic materials can enter the wastewater stream through indiscriminate dumping, improper handling of toxic materials, leaking vessels and pipes, or accidental spills.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

2.50A List three types of industries whose wastes could be treated by an activated sludge plant.

2.51A What factors influence the character of industrial wastewaters?

2.52A How would you attempt to solve a hydraulic overloading problem at an industrial wastewater treatment plant?

2.52B How can the pH of an industrial wastewater be adjusted (1) upwards, and (2) downwards?

2.52C Chemical oxidation (COD) measures the presence of (1) ______ and (2) ______, but not (3) ______ in organic materials.

2.52D List the three major nutrients required by microorganisms and four other elements that might be critical.

2.52E What are the most common causes or kinds of toxicity in industrial wastewaters?

2.53 Flow and Pre-Treatment Considerations

Because industrial wastewater characteristics may change significantly over a given period of time, a program for sampling, testing, and measuring the flow is essential.

Variations in production activity will change wastewater characteristics. Samples should be collected during each operating shift and during different stages of the finished product and raw product runs. Flows should be monitored continuously, even during cleanup and on weekends.

Daily or seasonal shutdown and start-up of a processing/production facility usually causes wastewater characteristics to vary greatly. This variation often causes problems in a treatment system. Biological treatment systems perform best on a uniform supply of a given source of food (BOD). If the food supply changes greatly, the biological process may not be able to adjust to the change. The impact of frequent shutdowns and start-ups on a treatment system should be carefully evaluated. Flow regulation procedures using holding tanks may be necessary to smooth out the flows (see Section 2.531, "Flow Control").

2.530 Flow Segregation

Considerable treatment cost savings may be achieved by processing only the wastewaters that contain pollutant materials in quantities exceeding the limits set forth in your local, state, or federal discharge permit. Consider classifying the processing/production facilities wastewaters into three categories (i.e., low strength BOD, medium strength BOD, and high strength BOD). You may find that it is possible to reuse the low strength BOD waters for cleanup purposes or dispose of it by discharge directly to a sanitary sewer system, by spray on fields, or by irrigation of pasture land.

Treatment of the medium strength BOD wastewaters (usually resulting from cleanup) may be possible by using a screen system to remove large solids and then processing the wastewater through an air flotation unit, plate and frame filter press or similar device. Since only 30 to 40 percent BOD and suspended solids reductions may be obtained from this treatment method, the dewatering process effluent (low in BOD/SS) may then be routed to the activated sludge system and will aid in diluting the high strength BOD wastewaters.

2.531 Flow Control

If your treatment plant experiences wide flow variations, these variations often cause problems in a treatment system. Depending on the daily operating mode of the processing/production facility, variations in instantaneous flow can be from very small to very great (a maximum of ten times the minimum). Each facility is obviously different, but large variations in flow may be smoothed with a surge or storage tank of about 10 to 20 percent of the total daily flow volume. Settling of solids will be a significant problem in a tank of this size, so that tank must either be mixed or some means must be provided for solids removal.

Control measures for water use in the process/production facility should be implemented. One of the most important methods of water use reduction is a complete and comprehensive training program of everyone involved in process/production. Additionally, roof gutters, downspouts, and facility storm drains may discharge to the treatment plant. These should be relocated and/or rerouted to appropriate drainage systems to eliminate charges for treating this water.

2.532 Screening

Discrete waste solids (such as trimmings, rejects, corn meal, and pulp) are effectively separated from the wastewater flow by various types of screens. Screening has many objectives including recovery of useful solid by-products; a first-stage primary treatment operation; or pretreatment for discharge to a municipal wastewater treatment system.

Screens should be located as close as possible to the process/production producing the waste. The longer the solids are in contact with water and the rougher the flow is handled (more turbulent), the more material will pass through the screens and the more the solids will become dissolved.

2.533 Grit, Soil, Grease, and Oil Removal

Fruit and vegetable, meat and fish, paper, and petroleum processing/production introduce large amounts of grit, soil, grease and oil to the waste stream. This material will accelerate equipment wear, settle in pipelines, accumulate in the treatment system, and create odors if not removed.

An aerated tank or lagoon can be provided to remove these wastes from the waste stream. This aeration system is usually designed to pre-aerate the wastewater while it aids the release of free and emulsified grease for surface collection. Additionally, separation and settling of grit, soil, and oil sludge are accomplished.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

2.53A How often should samples from industrial wastewaters be collected?

2.53B How can large variations in flow be reduced?

2.53C What kinds of waste solids can be effectively removed by various types of screens?

2.53D Why should screens be located as close as possible to the process/production producing the waste?

2.534 Central Pre-Treatment Facilities

Microorganisms that treat wastes in the activated sludge process will not work unless they are provided a suitable environment and are properly acclimated (adjusted to the wastes). A suitable environment may be provided by treating undesirable or toxic constituents in industrial wastes at the source where they are produced or at a central pretreatment facility (Figure 2.14).

Frequently the most economical method of treating toxic or undesirable wastes is at the source. If possible, do not allow these wastes to enter the plant wastewater or if they do, treat the waste in as concentrated form as possible, before it becomes diluted with other wastewaters. Source pre-treatment is appropriate for extreme pH levels, inert suspended solids, oil, grease or toxic materials (such as heavy metals).

Figure 2.14 shows a typical industrial pretreatment facility. The processes and the order of treatment will depend on both the type of industry and waste constituents. The first process is pH adjustment. Many manufacturing processes produce either high or low pH waste streams on either a continuous or batch basis. If source pretreatment does not reduce these pH variations to within acceptable ranges, central pH control facilities must adjust the wastewater pH to near neutral levels. Neutralization chemicals may be added and mixed in pipelines or in neutralization tanks. Figure 2.14 shows the pH adjustment process before the equalization tank. Some plants adjust the pH after the equalization tank. Location of the neutralization process depends on the type of industry and type of wastes being treated. See Chapter 6, "Industrial Waste Treatment," Section 6.3, "Neutralization," for more details.

Industry frequently uses special screens and microscreens to remove flotable and settleable solids instead of using primary clarifiers. These coarse or large solids are usually removed before the flow equalization tank. Removing these solids now will reduce unnecessary clogging and wear on downstream pipes, pumps, aerators and clarifier mechanisms. Also this process will help avoid odor problems that could develop from the settling out of solids in the equalization and emergency basins. For more information

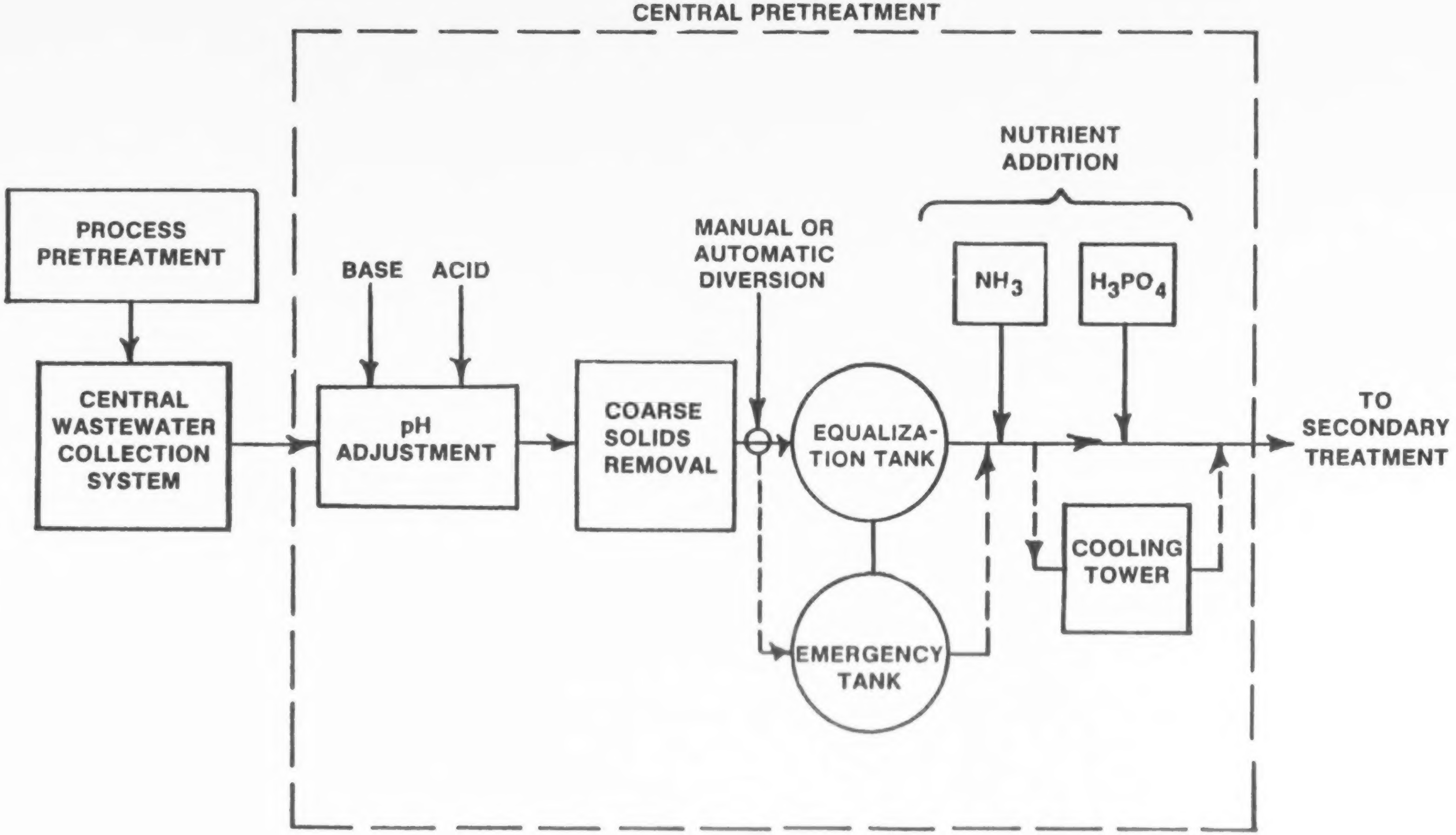

CENTRAL PRETREATMENT
PROCESS PRETREATMENT
CENTRAL WASTEWATER COLLECTION SYSTEM
BASE
ACID
pH ADJUSTMENT
COARSE SOLIDS REMOVAL
MANUAL OR AUTOMATIC DIVERSION
EQUALIZATION TANK
EMERGENCY TANK
NUTRIENT ADDITION
NH_3
H_3PO_4
COOLING TOWER
TO SECONDARY TREATMENT

Fig. 2.14 Control of the influent hydraulic and organic loading to the secondary biological treatment process

see Section 6.2, "Screening and Microscreens," in Chapter 6, "Industrial Waste Treatment."

Biological treatment processes work best if they receive fairly constant hydraulic and organic loadings. Equalization and emergency tanks are used by industry to store peak loads for release and treatment during periods of low loadings. Fluctuating flows (hydraulic loads) are usually smoothed out by allowing all wastewater to flow into the equalization tank and by pumping the wastewater to be treated out of the equalization tank at a constant flow rate. Variations in organic loadings are smoothed out by mixing the wastewater flowing into the equalization tank with the water already in the tank. By the use of effective mixing (such as with propellers, stirrers or aeration), the organic content of the wastewater in the equalization tank can be kept fairly constant, thus providing a constant organic load to the activated sludge process.

Emergency basins or storage tanks are usually kept empty or almost empty so that there is plenty of room to store any process spills or wastewater diverted when treatment processes are upset. Wastewater may be diverted automatically on the basis of signals from continuous monitoring equipment (total organic carbon, pH, or conductivity analyzers). Also diversion can be done manually based on results from continuous analyzers, grab samplers, or from a verbal warning of upset conditions from process operating personnel.

Generally, continuous monitoring and automatic diversion is the ideal approach for detection and isolation of process upsets. Unfortunately, continuous monitoring produces some severe operational problems in the form of sampling system and analyzer difficulties. Solids can plug the sampling lines and the analyzers may require considerable maintenance. To avoid these problems, some plants rely on the analysis of grab samples and notification by process operators when spills occur. Whether you use continuous monitoring or grab samples to detect spills and undesirable influent conditions, you must protect your biological treatment processes from unsuitable conditions.

Frequently industrial wastewaters lack the proper amounts of nutrients for proper microorganism growth and reproduction in the activated sludge process. The major nutrients of concern are nitrogen and phosphorus. Other nutrients such as calcium, magnesium, sodium, potassium, iron, chloride, and sulfur are needed by the microorganisms, but sufficient quantities are usually found in most process waters.

Nitrogen and phosphorus are needed for biological growth and reproduction in quantities approximated by a $BOD_5 : N : P$ ratio of 100:5:1 or a COD : N : P ratio of 150:5:1. If the nitrogen or phosphorus levels in the wastewater being treated are less than the values indicated by these ratios, more nitrogen can be added in the form of ammonia (usually as 30 percent aqueous) and phosphorus as phosphoric acid (usually as 75 percent aqueous). When these nutrients must be added, they are metered into the wastewater from the equalization tank or recycle sludge streams before the aeration tank. The additions are based on the difference between the desired amount and the actual amount in the wastewater being treated.

When the wastewater being treated has been heated by a production process, the water may have to be cooled before biological treatment, especially during the warmer summer months. Biological activity and treatment effectiveness usually drops rapidly at water temperatures above 99°F (37°C). Cooling towers are sometimes installed where heated discharges can cause problems. Usually a portion of the influent flow, or in extreme cases, the entire influent flow, is directed over the cooling towers during the warmest summer months. Proper operation of these towers allows sufficient evaporative cooling for control of the aeration basin temperature.

Sometimes sufficient water cooling will occur from aeration in the equalization and aeration basins. Mechanical aerators can be especially effective. Diffused air aeration systems, however, can increase the temperature by 5 to 7°F (3 to 4°C) because of the hot air from the blowers. If excessive cooling is caused by surface aerators in the cold winter months, shut down the aerators (if possible) or add heat by using heat exchangers or steam.

Troubleshooting problems in central pretreatment facilities are similar to other treatment processes. If a spill occurs with a high initial oxygen demand, mechanical aerators may not be able to supply enough oxygen to maintain a minimum dissolved oxygen (0.5 mg/*L*) in the equalizing basin. When this happens, the basin may become septic and give off undesirable odors. If the aerators cannot deliver more oxygen, additional oxygen may be provided in the form of hydrogen peroxide.

Another possible problem with mechanical floating aerators is excessive cooling of the wastewater during cold winter months. If the water temperature becomes too low, the activity of the activated sludge organisms and the performance of the secondary clarifier may be reduced greatly. A partial solution to this problem is to shut off some of the aerators completely or to shut off all of the aerators periodically. You must keep the contents of the equalizing basin well mixed to avoid surges of waste organic loads or solids settling on the bottom of the basin. If a proper schedule is developed for turning the aerators on and off, you can provide sufficient mixing and keep the heat lost from the surface of the basin low.

If the aerators fail, carefully monitor the flows from the equalizing basin to the aeration tank using continuous analyzers or frequent grab samples. If the variation in organic loading, hydraulic loading or temperatures becomes much greater than normal, divert all or some of the flow to the emergency basin. When the aerators are returned to operation, the flow to the aeration basin should be increased gradually to avoid shocking the biological system.

When the nutrient flow stops, try to get the flow back on line as soon as possible. If the nutrient flow can be restarted in 24 hours or less, feed nutrients at twice the normal rate for the same period of time that the nutrient flow was off. If the nutrient flow will be off for more than 24 hours, try adding nutrients from bags such as agricultural or garden fertilizers.

2.535 Start-Up or Restart of an Industrial Activated Sludge Process

Once the wastewater has been properly pretreated and ready for the activated sludge process, the activated sludge biological culture must be ready to treat the wastes. Whether you are starting a new activated sludge process or trying to get an existing process back on line after the culture has been wiped out by a toxic waste, the procedures to develop a new activated sludge culture are similar.

New activated sludge cultures are started by obtaining "seed activated sludge" or activated sludge microorganisms from either a nearby municipal or industrial wastewater treatment plant. The amount of seed activated sludge needed depends on the hydraulic and organic loadings on your treatment plant. The greater the load, the more tank trucks of activated sludge seed will be needed.

Once the activated sludge seed has been added to the aeration basin, the level of the water in the aeration basin is usually maintained just below the overflow level. The aeration system is in operation. You want to increase the population of activated sludge microorganisms. This is accomplished by feeding the "bugs" a solution they can eat quickly and use efficiently for building more microorganism cells. The most common chemical feed is sodium acetate. These microorganisms also require nutrients for fast and healthy growth. The key elements are nitrogen and phosphorus. They also must be provided in the form of chemicals added to the wastewater. Usually ammonium sulfate and potassium dibasic phosphate (available in a dry form in bag quantities) are used because they are relatively pure and can provide an adequate buffer for pH control in the aeration basin. These chemicals are easily dissolved in small amounts of water.

Start-up procedures will vary with each industrial waste treatment plant. Usually the chemicals are added to achieve a ratio of COD : N : P of 150:5:1 or BOD : N : P of 100:5:1. Chemicals are added on a batch basis directly to the aeration basin (or indirectly through pump wells) until the microorganisms multiply to approach a MLSS level of 2,000 mg/*L*. Usually enough sodium acetate (food) is added in a batch to allow the bugs to feed for one to three days. Between batch feedings, periodic analyses of the aeration basin contents will indicate the rate at which the bugs are consuming the organic materials (oxygen uptake rate readings and filtered COD or TOC analyses) and the rate of growth of the bugs (MLSS analyses). These measurements will indicate the timing for future batch feedings. Experience indicates that you usually have to feed chemicals for about one week to produce a flocculating sludge.

Once a MLSS level of over 2,000 mg/*L* has been reached, the industrial wastewater may be introduced into the aeration basin. *THIS STEP MUST BE VERY GRADUAL.* Pump approximately 10 percent of the total industrial waste flow from the equalizing basin. Chemical feeding should be continuous if at all possible. This procedure allows the activated sludge microorganisms to slowly adapt or become acclimated to the industrial wastes so the wastes will not shock the delicate growth patterns of the activated sludge microorganisms.

Periodically take samples from the aeration basin in order to monitor the degree of biological growth and removal of organic wastes (oxygen uptake rate, MLSS, and filtered COD). After two or three days, if the monitoring results are favorable (i.e., high COD removal, MLSS increasing, oxygen uptake rates steady), the industrial waste flow input can be increased (20 to 25 percent of the total flow) and the chemical feed (food) can be reduced by a similar amount. Also, at this time, the permanent nutrient feed system (if any) should be started to assure an adequate supply of nitrogen and phosphorus.

This procedure is followed until all of the industrial wastewater flow (with no chemical feed) is being fed to the activated sludge process. The time for the acclimation process to be complete will vary with the industrial wastes being treated, but usually two to three weeks are required. Once the activated sludge process starts to generate excess activated sludge above the desired MLSS level, sludge wasting should be started to control the MLSS.

Portions of this section were taken from *BACKGROUND DOCUMENT, DU PONT ACTIVATED SLUDGE TREATMENT.* Permission to use the material in these two sections is sincerely appreciated.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

2.53E In general, where is the most economical location to treat toxic wastes?

2.53F Why do some industries require a waste pretreatment facility?

2.53G Why does industry use screens to remove coarse solids?

2.53H How can variations or fluctuations in influent organic loadings be smoothed out before the aeration basin?

2.53I What chemicals are used to provide nutrients in the form of nitrogen and phosphorus?

2.53J Where would you obtain a "seed activated sludge" to get an existing activated sludge process back on line after being wiped out by a toxic waste?

2.53K Why must industrial wastes be added gradually to the aeration basin initially?

2.54 Operational Considerations (Activated Sludge)

The following discussion will center on specific operational problems experienced at various industrial wastewater treatment plants. Corrective action methods are also presented.

2.540 Neutralization

pH control systems may be installed to treat various process/production wastewaters. pH adjustment of this nature is usually done as a pretreatment process. However, lime, alum, and iron salts may be used in a pre-secondary chemical clarification process. In this case it is necessary to provide additional pH adjustment facilities to neutralize the normally high pH effluent (8.5 to 11.0) from the chemical clarification process. Abnormally high wastewater pH will result in loss of activated sludge system efficiency and cause settling problems in the secondary clarifier. A consistently alkaline waste (high pH) can be neutralized by using carbon dioxide (CO_2). Boiler stack gas and a compressor delivery system could be a source of carbon dioxide.

If a high pH wastewater is a problem because you use lime, alum or iron salts as a settling aid, consider the use of polymers instead.

If the pH is too low (acid), the pH can be increased by the addition of lime ($Ca(OH)_2$) or caustic soda (Na OH). The activated sludge process usually operates satisfactorily in a pH range from 6.5 to 8.0.

2.541 Nutrients

Nutrients, especially nitrogen and phosphorus, can be critical in the performance of the activated sludge system. The exact point at which nutrients become critical depends on your type of treatment process and how you operate it.

Remember that all applied nutrients must be in a soluble form to be used by the microorganisms. The addition of nutrients should be accomplished at a point where the incoming wastewater is highly mixed, preferably in the aeration basin.

The quantity of nutrients added to the treatment system should be based on the desired BOD reduction and the amount of the nutrient deficiencies. The amount of nitrogen and phosphorus required to treat a waste can be estimated from the quantity of sludge produced per day. The pounds of nitrogen required per day is equal to 10 percent of the volatile solids (on a dry weight basis) produced each day. Phosphorus requirements are one-fifth the nitrogen requirements. The amount of nutrients which have to be added each day is determined by the difference between the quantity required and the quantity available in the wastes.

Typical supplemental nitrogen is provided by using aqueous ammonia or anhydrous ammonia. Supplemental phosphorus is provided by using dissolved triple superphosphate, phosphate fertilizer, or phosphoric acid (a waste acid from aluminum bright dipping facilities).

When the supply of nitrogen and phosphorus from the wastewater is below that required by the microorganisms in your biological treatment process for extended periods of time, filamentous organisms may begin to predominate and cause sludge bulking in the secondary clarifier.

2.542 Daily System Observations

Daily observations of the bacterial population must be made to observe developing system changes and stress conditions so that proper action may be taken before overall treatment efficiency is affected. Under normal conditions, the bacterial population is composed primarily of small bacteria with large numbers of stalked ciliates and many free swimming ciliates and rotifers (Section 2.32). The presence of these higher forms gives you the indication that the process is operating properly. The following conditions have been found to cause the disappearance of the higher forms.

1. DO levels below 3.0 to 4.0 mg/*L*: With a high mixed liquor solids, it is possible that the oxygen transfer efficiency is impaired at lower DO concentrations. Additionally, filamentous growth may predominate.
2. High organic loadings: When the process is in the dispersed growth phase, it has been observed that the higher forms do not compete as well as the simpler bacterial forms.
3. Toxic substances or nutrient deficiencies: These conditions will affect the growth and maintenance of the higher forms.
4. pH control: If the pH control system is not operating properly to adjust the pH to near neutral, ciliates and rotifers will not adapt to pH fluctuations and will disappear.

2.543 Return Activated Sludge (RAS)

In most cases the RAS values for industrial waste treatment systems are the same as for municipal systems as discussed in Section 2.2. However, some systems experience a sludge with low compacting characteristics (high SVI). This is usually, yet not always, the result of conditions shown in Section 2.23, Table 2.3, on page 44.

2.544 Waste Activated Sludge (WAS)

An activated sludge plant, operating at a high rate (or low sludge age) will produce 0.5 to 1.0 pounds of microorganisms for each pound of BOD removed. In addition to the production of up to 0.5 pounds of microorganisms per pound of BOD removed, added sludge results from the non-biodegradable suspended solids, both volatile and nonvolatile, in the influent to secondary treatment. Consequently, it is common for the total secondary sludge production to be 0.8 to 1.0 pounds per pound of BOD removed. Sludge from secondary treatment systems is still biologically active and will putrefy. This can cause an intolerable odor. If the sludge contains no domestic wastes, it may be possible to spread and dry the sludge quickly on a disposal site or agricultural land, and then plow it into the soil.

Secondary sludge is difficult to dewater as compared with primary sludge. Raw, undigested secondary sludge has a total solids content of only one-half to one percent in air systems and one to three percent in pure oxygen systems. In addition, the cellular matter in the sludge is only fifteen percent solids. Unless the cell membranes are ruptured, microorganisms cannot be dewatered to greater than ten percent solids. Cells can be ruptured by heating or slow freezing although natural freezing can be used in some climates.

An alternate method of handling WAS from a treatment system that operates seasonally is to divert WAS to a lagoon. At the end of the season, the solids from the lagoon are periodically returned to the aeration system for "complete" oxidation during the off-season period.

2.545 Clarification

In industrial waste treatment systems, sludge settling often is significantly affected by influent characteristics variations. As a result of these variations, the settling characteristics of the sludge are extremely critical. Therefore, clarification rates of less than 400 gpd/sq ft (16 cu m per day/sq m) may be necessary to obtain proper operation.

If you observe a gradual decrease in percent solids removal over a period of time, this reduction may be the result of grit and silt accumulation in the aeration basin. The grit and silt are not carried out in the effluent, remain in the basin, and reduce aeration volume and detention time. A higher volatile content of the sludge would be indicative of this condition. A lower volatile content would occur only if the aeration basin's contents are well mixed. In this case there should be no settling nor accumulation of grit and silt.

If this condition exists, make every attempt to increase the efficiency of your grit removal process. If you do not have grit removal facilities, make every effort to increase the mixing in the aeration system to prevent the settling of solids in "blind" or "dead" areas (typically corners). If none of the above control methods are available to you, consider cleaning your aeration basins on a yearly basis if necessary. If you operate a municipal treatment facility and find grit and silt are coming from an industrial source, make the industry remove the grit and silt by pretreatment methods. Industry should not be allowed to dump this material into a sewer.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

2.54A Where should nutrients be added to a wastewater?

2.54B List some typical sources of supplemental nitrogen and phosphorus.

2.54C What factors or conditions have been found to cause the disappearance of higher forms of microorganisms from the activated sludge process?

2.54D What items could cause a *GRADUAL DECREASE* in percent solids removal from an activated sludge process over a period of time?

NOTICE

The following Sections 2.55 through 2.58, were prepared by the operators of actual industrial wastewater treatment plants. These operators have described procedures they use to treat industrial wastes by the activated sludge process. You must remember that there are many types of industries and that the waste flows and constituents will be different at every treatment plant. The intent of the following sections is to provide you with ideas that might work for your industrial waste treatment activated sludge plant.

2.55 Pulp and Paper Mill Wastes by James J. McKeown

STOP POLLUTING
STOP POLLUTING
STOP POLLUTING
STOP POLLUTING
STOP POLLUTING
STOP POLLUTING

Industrial wastewater treatment plants are designed in much the same manner as municipal plants; however, there are some important differences in treating pulp and paper mill wastes. Before any waste stream can be treated, both the average and range of fluctuations of flows and waste constituents must be measured, recorded and analyzed.

2.550 Need for Recordkeeping

The format for recordkeeping will usually be prepared by the environmental control supervisor. There are three basic reasons for keeping accurate records.

The first reason is to keep a history which helps troubleshoot problems which arise. Each entry onto the log sheet is made at the frequency needed to help locate trouble. Even so, the operator needs to be alert for trends which occur in between the log entries. Most log sheets call for pertinent remarks and the operator should make use of this column to note unusual conditions or to simply enter "all's well." Your record will be read by the person relieving you in order to pick up the operation. You know the things most helpful to you when starting a shift and it's simply a matter of doing likewise for your relief.

The second reason has to do with accounting for the operation of the plant during appropriate times, such as, weekly or monthly. If the operator should fail to make an entry and must estimate a value, the value should be footnoted accordingly. Failure to enter even routine data may prevent a calculation from being made. Serious mechanical problems or chronic symptoms of future problems should also be noted so the work orders can be issued to correct the problem.

The last reason is that records are legal documents which will protect the company from unjust claims. In other words, the company may have to prove that its operations were normal during a certain time period. The only way this can be accomplished is by use of the actual operating data. Therefore, it is very important to keep accurate records. Don't forget that all recorder charts are also a part of the official record. You may be asked to make notations on these charts as part of the accounting procedure and it's usually a good idea to initial the note. Another good idea is to make a note on your log sheet each time you mark the recorder chart.

2.551 Wastes Discharged to the Plant Collection System

In most industrial systems, departments or small networks of sewers are monitored individually. The control of wastewater in these networks is often the responsibility of production personnel. Experienced production personnel know that certain conditions in their area will result in abnormal discharges to the sewer. With proper communications between operating and waste treatment plant personnel, an alarm can be sounded either before or right after a spill actually happens. A quick phone call will allow emergency measures to be implemented in time to prevent operating problems. Everyone must encourage the necessary communications to give waste treatment personnel all the advance notice they need to properly operate the plant.

Several key sewers may be monitored continuously. In such a system the wastewater treatment plant operator can usually read the recorders to see if all the sewers contain normal quantities of wastewater. The use of centralized instrument panels both in the mill production area as well as the treatment plant will allow confirmation of a particular condition.

Operators should understand the reason why each water quality indicator is being monitored and if necessary, how the sensor works. In highly automated systems, the operator may use instrumentation personnel in order to maintain the proper calibration and operation of each sensor. However, even in this case, a basic understanding of the instrument or electrode is useful.

The most common control sensors which are used in pulp and paper mills are conductivity, flow, pH and turbidity. Special situations may be monitored to determine temperature, color, sodium, COD, TOC, or TOD. Oxygen respiration may also be monitored to detect overloads or spills. Continuous bioassays may be required at certain installations and DO is used to control aeration in activated sludge plants. Treatment plant personnel should be aware of the meaning of changes in the values of each water quality indicator at each sampling point.

The operator should be familiar with certain mill waste flow and constituent recorder patterns (variations) which are likely to occur in each sewer, so that appropriate control actions can be initiated. For example, a modest increase in conductivity accompanied by a low pH indicates that acid is probably being discharged into the mill sewer. However, if both conductivity and pH are quite high, then an organic discharge containing black liquor is the likely event. Further, if flow measurement is available, the operator should be able to determine the potential severity of the discharge. The operator should know what combinations of readings to look for and what actions are necessary in each case to control the situation. Many mills use continuous recorders with signal alarms to alert the operators that a particular sewer is exceeding its normal limit. However, whether communication is automatic or by person to person contact, most situations have a history of occurrence and can be properly handled using predetermined control measures.

If a spill is detected by the sensor system, the operator should be able to verify the spill. A phone call to the mill operating area may be sufficient to learn how long the event is likely to continue. With this information, a decision can then be made on the procedures to use to control the spill. Industrial control systems often use emergency storage tanks or spill ponds which can be filled quickly to protect the treatment plant.

Knowledge about the nature and duration of an emergency upset is a necessity for proper management of reserve storage capacity. These diverted wastes can later be bled into the treament plant at controlled rates.

2.552 Variables Associated with the Treatment of Paper Mill Wastes

NUTRIENT CONTROL

The wastewater usually does not have enough nitrogen and phosphorus to support bacteriological growth. Thus, facilities are often installed to add these nutrients to the wastewater before biological treatment. The proper amounts of these nutrients must be added because too little or too much may create problems. The operators should be familiar with their nutrient feeding systems and in cold climates, the temperatures at which certain nutrient chemicals will freeze. Many wastewaters only require nitrogen addition because there is enough phosphorus in the wastewater as a result of boiler water corrosion control and cleaning operations.

Experience with BOD removal at the lowest possible nutrient addition rates will allow the operator to properly control the addition rate. Soluble ammonia nitrogen and phosphorus generally need not exceed 0.5 and 0.25 mg/*L*, respectively, in the final effluent. Many systems are providing adequate treatment at effluent concentrations of 20 to 50 percent of these values. If final effluent nutrient values are considerably lower than these values, then additional nutrients may be necessary.

FOAM CONTROL

Another additive in pulp mill wastewater systems is a defoamer. Some pulp mill effluents foam because the wood soaps are not fully captured in either the tall oil or recovery systems. The chemicals which cause foams are oxidized during biological treatment. However, if foaming isn't controlled in the biological plant while treatment is taking place, a variety of problems may result, including frothing of mixed liquor solids thereby removing these solids (organisms) from the system. Foam can also engulf and shortout motors and other electrical equipment. Also, foam will cause certain level recorders to misinterpret the true liquid level and this can be troublesome if flow measurement is affected. Foam may also cause an air pollution problem, especially if it dries and becomes windborne.

Foam is generally controlled by water sprays or dosing with an antifoam chemical. The object of either approach is to cause an uneven distribution of surface tension in the foam. The spray also provides a physical impact which busts the foam and creates channels for subsequent drainage through the foam.

Defoaming chemicals are very expensive and their applications should be carefully controlled. The delivery system can be by overhead spray or by using the aerator to distribute the chemical into its own spray. Either system has been used with success in the paper industry. Most paper mills use metering pumps to feed defoamer. The chemical is added continuously at a predetermined rate. If foam volume increases, the chemical dose is increased for a short period of time and then reduced to the baseline again. Excessive use of defoamers may also place an added oxygen demand on the system which is undesirable. Automatic systems respond to conductivity or photoelectric sensors. When the foam reaches the sensor, the defoamer chemical is applied in steps until the foam recedes below the sensor. Chemical suppliers will gladly recommend procedures which reflect their experience.

pH CONTROL

The plant may be equipped with a neutralization system where acid or caustic is added prior to the mixed liquor tank. Most facilities add these chemicals prior to the primary clarifiers. However, some plants bypass the clarifiers with large volumes of bleach plant wastes and, in this case, pH adjustment is accomplished in a blend tank where bypassed wastes join primary effluent.

Hydrated lime, $Ca(OH)_2$, and caustic, NaOH are two of the common alkaline solutions used to increase pH while sulfuric acid, H_2SO_4, is the common acid solution. Control of pH variations is probably more important than the actual pH value. However, most mills have a high and low pH target value which must not be exceeded and pH should be adjusted to fall within this range.

Most pH control systems are automatic and are based upon pH and flow sensors placed downstream from the blending point. Acid and caustic make up requires that the operators follow prescribed safety rules because of the danger involved in handling these concentrated chemicals.

PRODUCT RELATED SITUATIONS

Treatment of pulp and paper mill wastewaters is similar in many ways to the treatment of municipal wastes. The machinery is identical in many cases. However, the operator who worked in a municipal plant will quickly become aware of some additional differences which depend on the type of pulp and paper being produced. These differences are reviewed here.

The paper industry has several types of pulp mills and manufactures a large number of grades of paper. To a large extent the waste treatment systems operations will reflect the particular mix of pulp and paper being made each shift. Thus, a knowledge of which grades are being produced can be an important factor in the operation of the plant. We cannot cover all of these product related differences in this section. However, the topics of flow, settleable solids, color, and odor can be discussed in general terms.

1. *FIBER* — The paper industry manufactures products made primarily of cellulose. The cellulose must be treated in the mill in a variety of ways which include cleaning, blending, refining, screening, bleaching, trimming, and drying. In many of these operations, the cellulose is pumped from one unit process to another. In order to efficiently process the cellulose into paper, the fibers must be separated (diluted) for some unit processes and matted (molded) for others. The result is that the cellulose is contacted with large quantities of water at various points in the process.

   This water is later removed from the cellulose and much of it is reused. The recycle system in a paper mill actually retains 3 to 10 times the amount of water sewered. The paper industry is continually looking for new ways to reuse much of this water. In many cases, the mill uses internal treatment to renovate these waters before reuse in showers or for stock dilution.

   Also, the effluents are generally treated within the mill before being discharged to the sewer. Most of the usable fiber is scalped from the water by a variety of savealls. The savealls may be screens, filters of various sorts, dissolved air flotation units, or mechanical clarifiers. See Chapter 28, "Industrial Waste Treatment," for details on these processes.

   When the recycle system is working properly, the treatment plant receives moderate quantities of water containing the fine cellulose particles and dirt which have been deliberately separated from the paper. However, when the recycle system is out of balance, large quantities of water and cellulose may be sent to the sewer.

   Most of these cellulose fibers settle readily and will clog screens and impair the passage of effluent if adequate mixing or dilution isn't maintained in the sewers. Further, when the fibers reach the primary clarifier, they settle readily and increase the load on the rakes. Most clarifiers are designed to handle this load without overloading, but the sludge removal rate is usually increased to keep the torque in control.

2. *FLOW* — Large quantities of extra water may also accompany these abnormal fiber discharges. Again, the size of the plant should be adequate to handle these surges. However, the operation may require adjustment of chemical feed and use of standby pumps after hydraulic surges have reached the plant.

   Further, most paper mills operate around the clock. Thus, flows are fairly constant and don't decrease during the night as happens with the flow to municipal plants.

3. *SETTLEABILITY* — If the paper plant contains a pulp mill, some further differences may be evident. The pulping of wood separates a number of chemicals from the fiber. These chemicals are believed to cause higher SVI levels in biological sludges produced during treatment. In the case of treating 100 percent pulp mill effluent, secondary clarifiers are designed with overflow rates lower than systems processing only domestic wastes in order to accomodate this slower settling floc. Also, the final effluent may contain slightly higher suspended solids concentrations where 100 percent pulp mill wastes are being treated.

4. *COLOR AND TURBIDITY* — The chemicals extracted from wood are colored very much like swamp water which contains vegetative extracts. Thus, the wastewater will generally appear yellowbrown. A wastewater can be clear in terms of suspended solids, although it is still colored by dissolved solids. Wastewater with a dissolved color will change in color with changes in pH as well as mill operations.

   Certain papermills use dyes or pigments to color the fibers. Tissue paper, construction paper, and a variety of specialty products are examples of grades which are colored. The wastewater associated with these grades will also be colored. Mills with one paper machine produce effluents which change in color every time that the papermaker changes the dye. However, the color change isn't as noticeable in effluents from mills with many paper machines because the colors blend toward neutral and often appear gray. Most dyes are oxidized and thus disappear during biological treatment.

   Mills making filled grades or using starch will produce waters which appear white. Starch will usually degrade in biological treatment and the cloudiness and turbidity will disappear during treatment. Some mills use titanium dioxide and talc to fill the paper sheet. These very fine white particles have high refractive powers and may not be completely removed during treatment. Thus, the final effluent will contain white solids. Also, the return activated sludge may appear white because it contains large quantities of these inorganic pigments.

5. *ODOR* — The odor of the water discharged from a pulp mill will reflect the chemicals used and produced in the pulping process. In most cases, these odors are associated with gases which were captured in the process water back in the mill. When these waters arrive at the treatment plant and are aerated, the gases are stripped from the wastewater. The extent to which these gases are present in the wastewater depends on the pulping process and the extent to which the waters are stripped of gas prior to discharge to the sewer.

EMERGENCY SYSTEMS

The plant probably has some emergency features which are seldom used. Industrial systems must be able to be started up and shut down in accordance with production variations. In many cases, these are planned far enough in advance to turn down or shut down the plant in an efficient manner. However, occasionally, because of an equipment failure at the plant, personnel have to respond quickly by employing seldom used facilities. The operators should run through periodic drills which simulate their reactions to these emergencies so there will be no delay when a real emergency occurs. Examples of seldom used facilities are standby pumps, diversion valves, spill tanks and lagoons as well as feed tanks used to supply organic load to build up an activated sludge culture prior to plant start-up. Further, spill tanks should normally be operated empty so their capacity is available during an emergency. After the tanks are used to scalp a spill, they should be emptied (usually gradually) at a rate which will allow the plant to treat the wastewater adequately. However, the goal should be to empty them as quickly as possible because the plant is susceptible to upset if another spill should occur which is larger than the reserve spill capacity. The spill tank is often used to store the waste for use during the shutdown period.

2.553 Start-Up and Shutdown Procedures

The paper industry has occasion to shut down and start-up an activated sludge plant for several reasons. Holidays, maintenance (preventative and emergency), process upsets, strikes, and scheduled production reductions may require that the activated sludge plant be turned down or shut down. The procedures for shutdown and subsequent start-up vary with the nature and duration of the shutdown, as well as the weather expected during the shutdown.

For short shutdowns a set of action plans must be developed to alleviate potential problems in line with some interim goals. The goals must be selected prior to each planned shutdown.

2.554 Management of Shutdowns and Start-Ups

by W.A. Eberhardt

WHY MANAGE SHUTDOWNS AND START-UP?

The performance of an activated sludge plant improves with increasing stability in influent loadings (waste composition and volume) and environmental conditions (pH, temperature, DO). Typically, as the steady-state condition is lost, discharges of suspended solids and BOD increase. Also of significance, once lost, the favorable performance associated with steady-state operation is not quickly regained.

Shutdown/start-up conditions have a high potential for producing a loss of biological equilibrium or steady-state. In addition, shutdowns/start-ups increase the risks of personal injury and produce abnormally high operating costs due to the new or unusual conditions typically experienced.

As an operator, it is your responsibility to the environment, your employer, and yourself to prevent or minimize the potential adverse impacts of a shutdown/start-up. To adequately meet your responsibilities, you must carefully manage the situation.

WHAT IS A SHUTDOWN/START-UP?

Shutdown/start-up is a situation whereby the normal wastewater feed is interrupted, or, one or more of the activated sludge support systems (such as aeration) malfunctions. The result is that the biological process is prone to lose equilibrium. Typical circumstances surrounding a shutdown/start-up are:

A. Interruption of Normal Feed
   1. Manufacturing interruptions (weekends, holidays, annual shutdown, equipment failures)
   2. Manufacturing abnormalities (spills, process changes or tests, product changes)
   3. Feed support loss (failure of a feed pump)

B. Interruption of Biological Support Systems
   1. Mechanical failures or planned outages (recirculation pumps, aerator, chemical feed pump)
   2. Runout of a chemical (nutrient, neutralization, polymer)

HOW CAN I MANAGE SHUTDOWNS/START-UPS?

To successfully manage shutdowns/start-ups, you must have *OBJECTIVES* and *GOALS*, and a *PLAN FOR IMPLEMENTATION*.

1. *OBJECTIVES AND GOALS* — Several basic objectives to be accomplished during shutdowns/start-ups are:
   1. Maintain satisfactory/legal process performance,
   2. No personal injuries, and
   3. Maintain least cost for satisfactory performance.

   For each objective, specific goals must be established. Table 2.7 provides some suggested goals. For example, one goal toward achieving the process performance objective is to maintain a constant F/M ratio. This would prevent one or more of the potential problems cited for failure to control or change the ratio.

   YOU must customize the suggested objectives and goals to your operation.

2. *PLANNING* — The shutdown/start-up plan is a strategy to accomplish your selected goals. The plan is necessary for both scheduled and sudden occurrences. The plan may be formally typed in a manual or written in a log book. This plan should include the specific activities and associated timing and responsibilities necessary to overcome all identified barriers to accomplishing each goal. For example, the shutdown might involve discontinuance of wastewater from manufacturing — a barrier to maintaining a constant F/M ratio. Your plan might call for storage of wastewater in a basin in advance of the shutdown with provision to pump it to the process during the outage (holding wastewater in a basin at all times might be a continuing plan to cover unscheduled losses of process wastewater). Finally, your plan, as applicable, must be coordinated with other wastewater treatment *AND* manufacturing activities.

3. *IMPLEMENTATION* — Successful implementation of your plan requires:
   a. *COMMUNICATIONS* with involved and affected personnel and organizations before and during implementation,
   b. *DISCIPLINED EXECUTION* of the planned action steps,
   c. *EVALUATION OF RESULTS* during execution with appropriate plan adjustments, and
   d. *CRITIQUE* of results and performance after the incident with emphasis on learning for future improvement.

4. *SUMMARY* — The benefits of well managed shutdowns/start-ups include satisfactory and legal performance, fewer injuries, and reduced costs. To manage an interruption, you must identify its occurrence (actual or potential) and aggressively act to minimize its consequences. Success will follow if objectives and goals are established, plans are developed to achieve them, and plan implementation is coordinated, disciplined, and flexible.

2.555 The Periodic-Feeding (Step-Feed) Technique for Process Start-Up of Activated Sludge Systems[13]

by R.S. Dorr

NEED FOR EFFECTIVE START-UP PROCEDURES

Activated sludge biological treatment systems are being constructed in many locations across the country by pulp and paper mills. Process start-up of these high rate biological systems presents a complex problem. The plants currently in operation across the country prove that given enough time and attention these systems can be successfully started up. Time, however, is costly and often limited when dealing with discharge permit deadlines.

DEVELOPMENT OF THE START-UP PROCEDURE

The periodic-feeding technique which has been developed for the start-up of pulp and paper mill activated sludge systems is based upon the biological growth kinetics and physical microbiological concepts which govern the biological treatment process. Several statements are crucial to the development of this start-up procedure and are summarized below:

1. The concentration of microorganisms in the system influent (the mill sewer) is insignificant in comparison to concentrations found in domestic collection systems.
2. There exists a critical minimum mean cell residence time (MCRT) below which the system cannot function and the microorganisms cannot establish themselves.
3. The degree of flocculation of the microorganisms is influenced by the food-to-microorganisms ratio (F/M). At very high values of F/M, microorganisms are completely dispersed and will not settle, rendering the secondary clarifiers nonfunctional.
4. If the secondary clarifiers are for some reason nonfunctional, the mean cell residence time is equal to the hydraulic retention time of the aeration basins.
5. Increasing the food (soluble BOD) to a bacterial population beyond certain limits, does not necessarily increase the rate of population growth.

In view of these facts, a process start-up procedure should provide a means of controlling the food-to-microorganism ratio and/or the mean cell residence time to prevent dispersal and washout of whatever bacteria may be initially present in the system. Neither the soluble BOD concentration in the system influent nor the amount of bacteria in the system can normally be controlled during a process start-up.[14] The hydraulic load-

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[13] *This section was taken from "Development and Testing of the Step-Feed Technique for the Process Start-Up of Activated Sludge Systems," by R.S. Dorr,* PROCEEDINGS OF THE 1976 NCASI NORTHEAST REGIONAL MEETING," *NCASI Special Report No. 77-03, May 1977.* NOTE: *The original paper referred to this procedure as* STEP-FEED, *but this section uses the term* PERIODIC-FEEDING *to avoid confusion with the step-feed activated sludge process.*

[14] ***As an exception, bacteria from another similar activated sludge plant may be introduced by "massive seeding" techniques involving many truckloads of thickened sludge.***

TABLE 2.7 GOALS FOR SHUTDOWNS/START-UPS

Goals	Potential Problems	Action Plans
1. Maintain constant food characteristics	Solids in effluent SVI increase Low BOD removal Lost activated sludge organisms	Normal waste — Store prior to shutdown — Feed during shutdown Abnormal wastes — Minimize — Bypass to storage for equalization
2. Maintain constant food/microorganisms (F/M)	Solids in effluent SVI increase	Pre-Shutdown — Store waste — Lower MLSS During Shutdown — Feed stored waste — Reduce or stop wasting
3. Maintain nutrient balance (N, P, metals)	Solids in effluent Bulking Low BOD removal which persists	Assure in advance — Adequate supply of nutrients — Provisions for addition of nutrients
4. Maintain environment constant (temperature, pH, DO)	Solids in effluent Low BOD removal	Optimize aeration for — DO — Heat retention in winter — Heat loss in summer Introduce heat during prolonged winter usage Assure in advance — Supply of neutralization chemicals — Provision for addition of chemicals or store pre-neutralized waste
5. Maintain hydraulic loading control	Hydraulic surges Flows during periods requiring a "dry outage" Sludge recycle imbalances	Plan together with manufacturing people Use of surge/storage basins Closed valve motivation Gradual increase in loading at start-up
6. Necessary equipment functional	Power outage (light, equipment) Instrument air outage (valve positioning)	Advance provisions — Standby generators — Instrument air override — Use storage basins
7. Complete required maintenance on schedule	Less than optimum performance after start-up Production downtime for subsequent repair	Critical path planning Maximum prework Avoid shutdown items
8. No personnel injuries	Lack of safety equipment Difficult environment (no lighting) Abnormal (non-routine) tasks Inadequate staffing	Individual job safety — Analyses with appropriate follow-up — Safety training program
9. Cost optimization	Shutdown extension due to — Inadequate staffing Undertaking necessary work Provision of unnecessary equipment (generator for aerators)	Question shutdown needs Complete planning
10. Protect receiving stream	Spills Inadequate treatment	Comprehensive planning
11. Meet permit requirements	Inadequate performance and/or discharge monitoring	Meet all goals in this table

ing rate, however, can be regulated. This is the basis of the start-up procedure described in this section.

Assume a waste stream of 10 MGD and 100 mg/*L* soluble BOD were to be treated in an activated sludge plant designed to have a hydraulic retention time of six hours. Flow is introduced to the system along with normal amounts of nitrogen and phosphorus required, and aerators and recycle pumps are started. After the six hours of flow required to fill the basins and clarifiers, the following conditions exist:

1. The soluble BOD level throughout the system is 100 mg/*L*.
2. The amount of bacteria present is very small, existing only in the form of "seed."
3. The value of F/M is very high, and therefore the bacteria are totally dispersed.

At this point, the flow through the system could be allowed to continue at 10 MGD; however, this might be disadvantageous for two reasons. The "seed" microorganisms cannot possibly consume a very significant portion of the soluble BOD during the six hours in which it would pass through the system. Indeed, it may take several days under very similar conditions to consume the 100 mg/*L* in a BOD bottle. There is no reason to believe that the reaction will take place any faster inside the aeration basin. Therefore, constantly feeding the system a fresh supply of wastewater containing 100 mg/*L* soluble BOD provides no real advantage.

Additionally, since the bacteria are dispersed, 10 MGD of water containing whatever concentration of microorganisms that exist in the system would be flushed over the effluent weir of the secondary clarifier. This loss must be made up for by the rate of growth of the bacterial population. The six hour residence time could be at or below the minimum mean cell residence time required for growth; therefore, washout of any bacterial growth will occur. In any case, it would put the microorganisms to an extreme handicap in establishing themselves.

In this start-up procedure, the influent flow is shut off. The water within the plant is then recirculated between the secondary clarifiers and the aeration basins. With this method, the mean cell residence time may be made as long as necessary simply be retaining the entire mass of microorganisms within the system. The bacteria proceed to consume the soluble BOD present and subsequently increase in concentration, rapidly lowering the F/M value. Eventually, the energy level drops to a point where the bacteria begin to flocculate and the amount of food remaining becomes a limiting factor in further growth.

Now is the time to introduce more food to the microorganism population. Again, it might be disadvantageous to feed the full 10 MGD flow through the system for the same reasons stated previously. The flow instead is introduced at a gradually increasing rate, thus gradually accelerating the rate of introduction of available food to match the growing concentration of microorganisms. In terms of the food-to-microorganism ratio, "F" might be matched to an ever increasing "M" in a way to maintain a value of F/M that would neither inhibit the growth rate nor disperse the bacteria. As an additional advantage, a reduced rate of feed would produce a lower overflow rate in the secondary clarifiers, making them more efficient than normally possible. This fact could be used as justification for allowing higher than normal F/M values during the low flow portions of the start-up.

The value of F/M could ideally be held constant or gradually decreased by carefully regulating the flow rate through the plant. Practically, however, this is not possible due to uncertainties in the actual soluble BOD concentration in the waste stream and also because the flows cannot usually be regulated with any precision. Much more feasible from an operating standpoint would be to keep the value of F/M within a range that would eventually narrow down to the optimum when the system is started. The feed could be increased in a periodic step-wise manner as long as the period steps did not cause the F/M to exceed a "safe" level.

Although bacteria are the primary motivators in stabilizing the organic wastes, other types of microorganisms play an important role in an activated sludge system. More complex single cell organisms called protozoa act as scavengers devouring dispersed bacteria producing a highly clarified effluent. These protozoa also serve as useful indicators of the overall condition of the system. Because of their greater complexity and size, they are more sensitive to changes in their environment and can be more easily observed under a typical compound microscope.

The usefulness of microscopic indicators in this type of start-up scheme is obvious. Following each periodic (step) increase in feed to the system, the value of F/M will rapidly pass from a high level to one near the normal optimum. Timing the next periodic (step) increase is critical both to the viability of the microbial population and to the overall start-up time requirements. The F/M value may be guessed at based on measured MLVSS and either estimated BOD loads or rapid tests that approximate BOD such as COD to TOC analysis. These lab tests are very important during start-up; however, only by microscopic inspection can the system's energy level be immediately and directly confirmed. In addition, this observation may detect nutrient deficiency, low pH, low dissolved oxygen levels and other problems hindering most start-ups. The discovery by microscope of one of these defects is independent of plant instruments that may be as yet inaccurately calibrated or laboratory tests with which the technician is unfamiliar.

Besides producing a rapid and controlled growth of active microorganisms, the periodic (step)-feed procedure has several other virtues. Using this procedure, a full, active population may be grown from even the smallest amount of seed organisms. A bucket of activated sludge from another plant will contain all the types of microorganisms necessary to start a system and may be used if it is uncertain that they exist normally in the mill wastewater. This small population of microorganisms, when introduced during the zero-flow step, will proliferate and stabilize the F/M value within a matter of several days.

The periodic (step)-feed method minimizes the possibility of sudden kills of the active bacteria mass. The microbial population is extremely fragile during the early stages of its development, but it is also during this time that most of the wastewater flow bypasses the system. This effect reduces the possibility that a slug of toxic, inhibitory or high strength organic material in the waste stream could fill the system to a concentration that would endanger its growth.

Finally, there is no period of "population stabilization" after the target MLVSS level is attained using the periodic (step)-feed method. Often in the start-up of an activated sludge system by other methods, the types of microorganizms present in the system when the target is reached are not the same ones that will predominate during the normal operation. This is because the population produced by using these methods develops under conditions, such as the energy level, that are far removed from those prevalent after the target is reached. A considerable length of time may be required for a turn-over of the types of microorganisms represented in the population. Plant performance can be expected to be somewhat less than optimum during this period. By gradually "zeroing in" on the optimum F/M value, the periodic (step)-feed technique cultivates a highly diverse population of microorganisms which are more adequately suited for survival during normal operation.

2.556 Operating of a Municipal Plant Receiving Paper Mill Wastewater

by Anthony A. Leotta and W.A. Hopsecger

Operating experience described in this section were obtained from a treatment plant with present day domestic flows averaging from 2.0 to 2.5 MGD (7,570 to 9,460 cu m/day) and paper mill flows from 0.3 to 0.5 MGD (1,135 to 1,890 cu m/day). Paper mill wastewater averages 600 mg/*L* suspended solids and 250 mg/*L* BOD. Domestic wastewater is relatively weak and averages 75 mg/*L* suspended solids and 50 mg/*L* BOD.

Nutrient deficiencies are experienced at this plant. Urea is introduced into the aeration tanks to provide a concentration of 5 mg/*L* at the head of the aeration tank. Another satisfactory approach to solving the nitrogen deficiency is to bypass a portion (10 to 20 percent) of the primary influent directly to the aeration tanks. Nutrients which are usually removed by primary treatment are diverted to the aeration tanks to satisfy the nitrogen deficiency.

Mixed liquor suspended solids are adjusted to 2,500 mg/*L*. Experience seems to indicate that paper waste is difficult to consume by microorganisms and therefore may require more microorganisms than in most domestic treatment plants to do the job.

DO levels in the aeration tank are maintained between 2 and 3 mg/*L* throughout the entire tank. Too much air (over 3 mg/*L*) results in a breaking up of the floc and a resultant decrease in settleability. Too little air results in a loss of beneficial activated sludge bacteria and could result in an undesirable explosion of filamentous growths.

Optimum return activated sludge (RAS) flows range from 40 to 50 percent, depending on flow and secondary clarifier conditions. Return rates of 20 to 25 percent do not maintain the proper MLSS in aeration. Rates in excess of 50 percent cause an increase in overflow rates which result in bulking sludge flowing over the clarifier weirs.

Depending upon the type of solids in the return sludge, the wasting schedule is reduced during the autumn and winter season in order to maintain higher MLSS in aeration. Since microorganisms become less active (sluggish) in colder temperatures, MLSS are raised to about 3,000 mg/*L* during the colder seasons. Closer control of MLSS vs. suspended solids in return sludge is required during the colder season. Experience has shown that the ratio between MLSS and return sludge suspended solids should be about 3. In other words, with the best range of MLSS from 2,000 to 3,000 mg/*L*, suspended solids in the return sludge should be maintained between 6,000 to 9,000 mg/*L*. Wasting schedules are calculated to maintain this ratio.

The operating guidelines are summarized as follows:

1. F/M ratio <1.0
2. SVI around 200
3. MLSS of 2,500 mg/*L* (warm weather)
4. MLVSS, 70 percent of MLSS
5. DO, 2 to 3 mg/*L* throughout aeration tank
6. Return activated sludge rate, 40 to 50 percent
7. Return activated sludge suspended solids, 7,500 mg/*L*
8. MLSS/RAS SS, 3

2.557 Acknowledgments

Authors in this section on how to treat pulp and paper mill wastes included James J. McKeown, W.A. Eberhardt, R.S. Dorr, Anthony A. Leotta and W.A. Hopsecger. Reviewers of this section included Al Brosig, Anthony A. Leotta, Larry Metzger, David B. Buckley, Ray Pepin and W.A. Eberhardt.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

2.55A Why must accurate records be kept?

2.55B Why should the effluent from a pulp and paper mill activated sludge process contain around 0.5 mg/*L* ammonia nitrogen and 0.25 mg/*L* phosphorus?

2.55C Under what conditions might the paper industry shut down an activated sludge process?

2.55D Why is the periodic feeding (step-feed) technique for process start-up of activated sludge systems effective?

2.56 **Brewery Wastewaters** by Clifford J. Bruell

2.560 Operational Safety

In brewery wastewater treatment plants, as in other food or industrial treatment plants, there exists the potential of tremendous fluctuations within influent wastewater characteristics. This is especially true with respect to the organic content of the influent. A brewery wastewater treatment plant that receives an organic load of 25,000 pounds (11,000 kg) of BOD on one day may experience an organic loading of 50,000 pounds (22,000 kg) of BOD (or more) the following day. Economically it is impossible to design, construct and operate a wastewater treatment plant that will as a matter of routine, treat highly fluctuating loads or the entire potential load from an industrial plant. Therefore, a multifaceted waste load monitoring program to *CONTROL* the source of the wastewaters and to *CAPTURE FOR REUSE* valuable raw materials is essential.

Due to the nature of brewery operations and the characteristics of brewery wastewater, *MOST BREWERY WASTEWATER TREATMENT PLANTS ARE SMALL WASTEWATER TREATMENT PLANTS THAT DO THE WORK OF LARGE WASTEWATER TREATMENT PLANTS.* Therefore, a tight, well organized operation is imperative in order to meet NPDES permit goals. The various operational strategies described in this section are examples of what has worked best at a typical plant. These methods are *NOT THE ONLY WAY* to get the job done. Careful experimentation (where only one variable at a time is changed) is necessary to determine the best operating methods at every individual treatment plant. There is no substitute for experience and every operator has experience. The key to successful operation is using existing experience and to build on that foundation with new, well documented experience.

2.561 Sources of Characteristics of Brewery Wastewater

SOURCES OF BREWERY WASTEWATER

In the brewing industry, as in other food processing industries, there is always some minimal loss of raw materials. Brewing ingredients such as malted barley, rice, starch, hops and yeast often become part of the wastewater. Raw material losses can be controlled by the use of capture systems and recycle loops; however, it is inevitable that some portion of this material will become waste. The malting of barley requires large volumes of water which flushes from the grain concentrated organic materials throughout the malting process. To maintain sanitary conditions within a food plant, large volumes of cleaning solutions are required. These soapy solutions, that often have a high pH (caustic soda) and their associated rinse water, also become part of the brewery wastewater stream. A small portion of the product, *BEER* and brewery by-products (brewers yeast) are very concentrated (organically), and can enter the waste stream. On occasion, lubricating oils or other maintenance or utility materials (ammonia, glycol coolant, acids) may accidentally enter the sewer line. Together these items are the sources of brewery wastewater.

CHARACTERISTICS OF BREWERY WASTEWATER

Brewery wastewater that contains starches, sugars and alcohol can be characterized as organically strong. This means that the wastewater may often exert a BOD of 1,200 mg/*L* or greater (municipal wastewater often has a BOD of 200 mg/*L*). Much of this BOD is "soluble" or "dissolved" and only 10 to 15 percent of this BOD can be removed by primary clarification. Therefore, a highly efficient secondary treatment process, such as activated sludge, is necessary to successfully treat brewery waste. Nutrients such as nitrogen and phosphorus are often considered to be deficient within brewery wastewater. Textbook data often states that the ratio of BOD:Nitrogen:Phosphorus that is necessary to produce desirable activated sludge microorganisms is 100 pounds BOD: 5 pounds N: 1 pound P, within the influent to the aeration basins. If wastewater has a very high BOD, due to starches and sugars, then the nitrogen and phosphorus levels considered *NORMAL* in municipal wastewater would be deficient when compared to the BOD in brewery wastewater. If cleaning solutions (acids and caustics) are released rapidly to a brewery wastewater treatment plant (instead of being slowly metered), drastic pH fluctuations within the influent will result. This pH fluctuation (pH 4 to 10) can cause operational problems if the influent is not neutralized.

2.562 Brewery Wastewater Treatment Plant Tour

OVERALL PICTURE

A typical brewery wastewater treatment plant flow layout is shown on Figure 2.15. Typical data has been included to give you the "feel" of the relative operating conditions of this plant. To provide you with an overall picture of the plant, let's take a *WALKING TOUR* of the plant shown on Figure 2.15. At each location try to picture the equipment that would be seen and the process that is taking place. *USE YOUR EXISTING KNOWLEDGE OF WASTEWATER TREATMENT AND TRY TO RELATE IT TO THIS BREWERY WASTEWATER TREATMENT PROCESS.* Also, much of the other information within the remainder of this section on brewery wastewater treatment will be somewhat specific to the typical brewery wastewater treatment plant described.

PRETREATMENT OF WASTEWATER

To begin the tour let us start at the headworks of the plant. At this point the flow from various portions of the brewery, which is collected by a massive network of piping, valves, floor drains and sumps, is delivered to the wastewater treatment plant via a lift station and several gravity lines. An influent flow of 3.0 MGD (11,350 cu m/day) containing 1,200 mg/*L* BOD (30,000 lbs or 13,600 kg/day) and 250 mg/*L* SS (6,000 lbs or 2,700 kg/day) would be an average loading to this plant. The first step of the treatment process is bar screening. At this brewery the automatically raked bar screen removes can lids, cans, glass, pieces of wood, rags and balls of "grain and keg wax" that form within the sewer lines. Immediately following the bar screening step is the *GRIT REMOVAL CHAMBER* or grit channel. Grit at a brewery wastewater treatment plant consists of malted barley and hops. Depending on what raw materials are used, grains such as corn grits or rice might also be captured within a grit chamber. These brewing materials are readily settled and removed from the waste stream. Therefore, this grit material has some limited reuse value, an example of this would be as a compost mix additive. Estimation of the volumes of grit that are generated at various breweries is very difficult because these volumes would depend on whether malting was being done on site and the efficiency of the recapture systems. At this brewery between 0.5 to 1.0 cubic yards of grit per MG (0.1 to 0.2 *L*/cu m) of flow is generated.

A useful operational aid within the area of the bar screen is an in-line continuous monitoring pH meter. A meter at this location, with a low and high pH alarm, can alert an operator of *POTENTIAL pH PROBLEMS* long before they *BECOME PROBLEMS.* The magnitude of a pH fluctuation and the duration can alert an operator of the severity of the problem. An automatic/manual acid addition system is used to meter (pump) concentrated H_2SO_4 to neutralize caustic cleaning solutions. An additional recording pH meter is used to control/monitor the acid addition. At this brewery the acid addition step is done within the grit chamber area; however, a more desirable addition and monitoring point would be downstream of the surge tank or primary clarifier. Other brewers have successfully used automatic caustic addition systems (50 percent NaOH via pump) to neutralize acid spills. If an automatic caustic addition system is not present, stores of caustic materials such as lime or NaOH should be kept on hand for emergency situations (large acid spills).

After grit removal the influent wastewater stream enters a 0.5 MG (2,100 cu m) surge tank. Brewer production is often a batch process. A good example of this is the malting process. When a malting tank is drained of liquid within the "steeping out" process, this can exert an immediate high hydraulic load (8 MGD (30,000 cu m/day) flow rate) upon the wastewater treatment plant. The surge tank is used to catch this peak hydraulic load and then the waste can be metered to the plant at a controlled rate. Pumping from the surge tank at a controlled rate of flow eliminates shock loadings to the aeration basins and prevents disturbing the sludge blanket within all of the plant clarifiers. Another function of the surge tank is dilution of high strength organic wastes within the influent. Beer has a very high BOD that can exceed 200,000 mg/*L*. If an accidental beer spill occurred, consisting of 10 to 100 Bbls of beer (31 gallons/Bbl), this would be considered a major overload situation. A load of this magnitude, unchecked, could cause a plant process failure. However, when a surge tank is used, dilution will occur within the tank and the entire waste load is *METERED* into the aeration system. When the waste material then enters the aeration system at a slightly elevated organic concentration (rather than greatly elevated), it is possible to meet dissolved oxygen requirements and to form a desirable biomass. To facilitate mixing and dilution several floating aerators are used. These units rise and fall (float) just as the tank level does. These mixers achieve a small degree of preaeration. Oils and grease, within the waste stream, are also "conditioned" by the mixing action of the surge tank. These

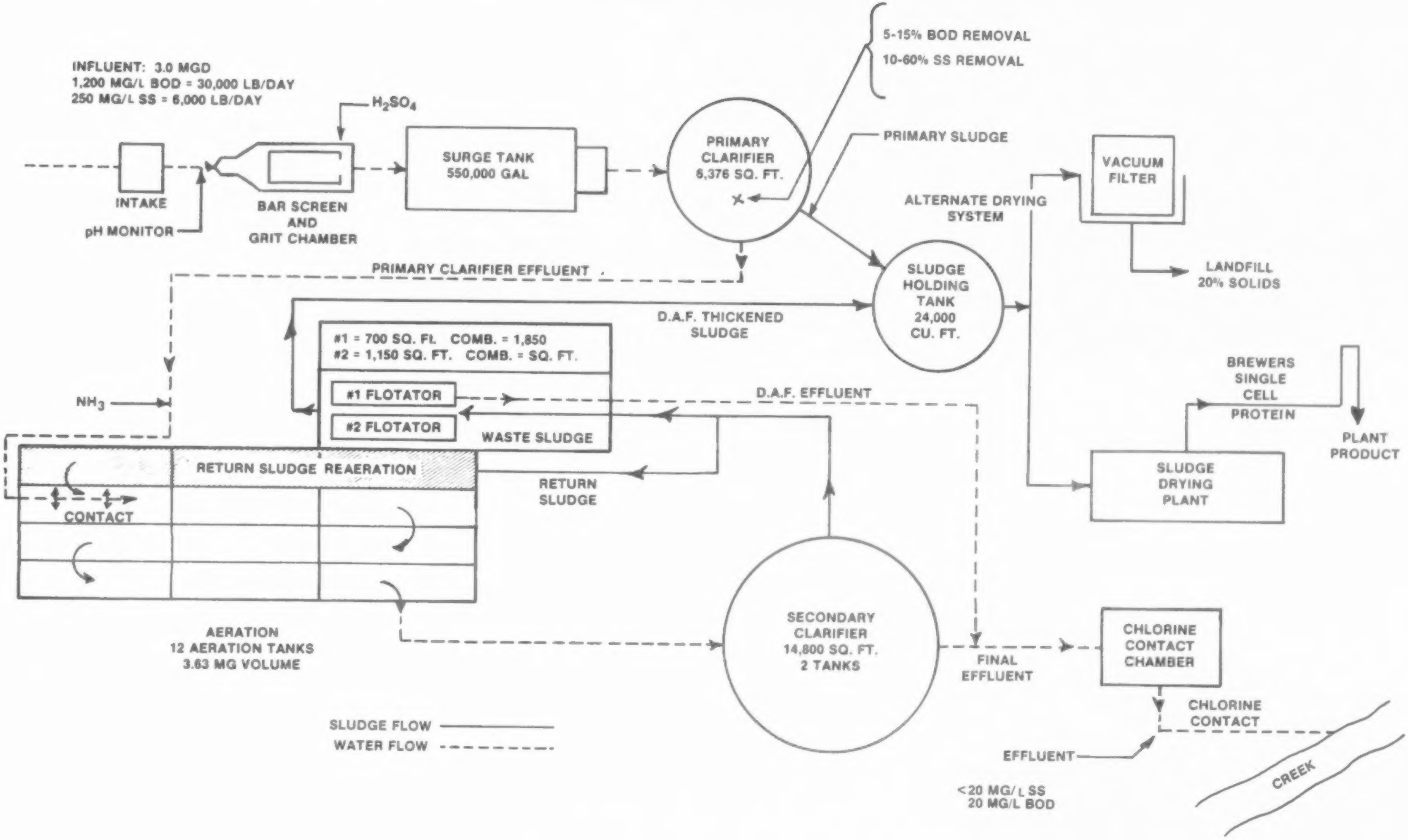
INFLUENT: 3.0 MGD
1,200 MG/L BOD = 30,000 LB/DAY
250 MG/L SS = 6,000 LB/DAY
H2SO4
INTAKE
pH MONITOR
BAR SCREEN AND GRIT CHAMBER
SURGE TANK 550,000 GAL
PRIMARY CLARIFIER 5,376 SQ. FT.
5-15% BOD REMOVAL
10-60% SS REMOVAL
PRIMARY SLUDGE
VACUUM FILTER
ALTERNATE DRYING SYSTEM
LANDFILL 20% SOLIDS
PRIMARY CLARIFIER EFFLUENT
SLUDGE HOLDING TANK 24,000 CU. FT.
D.A.F. THICKENED SLUDGE
#1 = 700 SQ. FT. COMB. = 1,850
#2 = 1,150 SQ. FT. COMB. = SQ. FT.
#1 FLOTATOR
#2 FLOTATOR
WASTE SLUDGE
D.A.F. EFFLUENT
BREWERS SINGLE CELL PROTEIN
PLANT PRODUCT
NH3
RETURN SLUDGE REAERATION
CONTACT
RETURN SLUDGE
SLUDGE DRYING PLANT
AERATION
12 AERATION TANKS
3.63 MG VOLUME
SECONDARY CLARIFIER 14,800 SQ. FT. 2 TANKS
FINAL EFFLUENT
CHLORINE CONTACT CHAMBER
CHLORINE CONTACT
EFFLUENT
<20 MG/L SS
20 MG/L BOD
CREEK
SLUDGE FLOW
WATER FLOW

Fig. 2.15 Flow schematic of brewery wastewater treatment plant

materials become slightly coagulated which results in an increased removal efficiency of floating oil and grease (F.O.G.) within the primary clarifier.

The control of the surge tank level is a manual operation controlled by the operator (level alarms and overflow provisions are present). Periodically the operator checks the surge tank level and adjusts the rate of waste pumping to maintain a desired level. From the surge tank the waste is pumped into the primary clarifier.

PRIMARY CLARIFIER

The primary clarification step typically removes 10 to 60 percent of the influent suspended solids. However, because brewery waste has a highly soluble organic content, a smaller amount of BOD removal is achieved at this point. A 5 to 15 percent BOD removal is typically obtained; this fact also indicates that only a small amount of BOD is associated with the solids removed here. Though oil and grease are not a major portion of the influent stream, some is skimmed from the primary clarifier surface along with small amounts of yeast, hops and grain hulls that tend to float within the primary clarifier. Sludge solids concentrations of materials removed from the primary clarifier typically range from 3 to 5 percent solids. Sludge blanket depths are measured periodically. Sludge pumping frequency and the rate of removal (pumping rate) are adjusted to maintain a minimum sludge blanket depth within the clarifier without causing "coning."

2.563 Nutrient Addition

Brewery wastewater is usually nutrient deficient. Most brewery wastewaters have a deficiency in both nitrogen and phosphorus. To supplement nitrogen, ammonia gas (or liquid) can be metered into the primary clarifier effluent. Some brewery wastewater treatment plants use phosphoric acid, H_3PO_4, as an additional source of phosphorus. At the brewery wastewater treatment plant under examination here, adequate quantities of phosphorus are present within the influent. This is due to the fact that phosphorus is derived from both malting by-products and phosphorus based cleaning solutions. However, within this plant, nitrogen is deficient.

A desirable organic strength to nutrient ratio is 100 pounds BOD: 5 pounds N: 1 pound P. In order to calculate the quantities of nutrient addition required it is first necessary to have some estimate of organic strength of the waste. To run a 5-day BOD test as an estimate of organic strength is impractical because it takes too long! This is especially true if nutrient addition rates have to be adjusted on a *DAILY* basis. Therefore, analysis such as chemical oxygen demand (COD) or total organic carbon (TOC) is necessary to provide relatively quick results. These tests can be run within several hours and a BOD value can be calculated once a BOD:COD or BOD:TOC ratio has been established. As an indication of the amount of nitrogen that is already present within the influent, NH_3-N analysis is performed on a 24-hour composite sample of the primary clarifier effluent. This same sample is used for other analyses such as TOC analysis. As an estimate of nitrogen content, NH_3-N analysis is used because it is easier to run than T.K.N. (Total Kjeldal Nitrogen) analysis. This usually ends up in a shift in the BOD:N ratio *FROM 100* pounds BOD:5 pounds N (T.K.N.) *TO 100* pounds BOD:2 pounds NH_3-N. (This is true because in this wastewater the ratio of 5 pounds T.K.N.:2 pounds NH_3-N holds true.) The same philosophy applies to phosphorus analysis (it is easier to run ortho-P analysis than total-P analysis).

An example of NH_3-N addition calculation sheet is provided (see the sample calculation). The basic principles of the addition procedure is to

1. Estimate the organic strength of the waste (via a quick method such as TOC).
2. Estimate the amount of nutrient already present (via a quick method such as NH_3-N).
3. Estimate the supplemental amount of nutrient required.

The sample calculation procedure is designed to allow addition of the nutrient on a continuous basis for 24 hours. Also, when the plant effluent analysis reveals 1.0 mg/*L* or greater residual of the nutrient that is being supplemented, this is an indication that the addition quantity is sufficient. If the residual is far above or below the 1.0 mg/*L* concentration, the addition ratio should be adjusted accordingly.

NUTRIENT ADDITION SAMPLE CALCULATION

Sample Data:

Item	Data
Primary Effluent, 24-hour Composite Total Organic Carbon (TOC)	554 mg/*L*
BOD:TOC Ratio	2.2:1
Calculated Sample BOD 2.2 × 554 mg/*L*	1,219 mg/*L*
Estimated Flow for the Next 24 hours	3.3 MGD
Final Effluent, 24-hour Composite NH_3-N Concentration	0.88 mg/*L*
Primary Effluent, 24-hour Composite NH_3-N Concentration	8.36 mg/*L*

SAMPLE AMMONIA ADDITION CALCULATIONS

1. Estimate the present day's BOD loading in pounds of BOD per day.

$$\begin{aligned}\text{BOD Loading, lbs/day} &= \text{Flow, MGD} \times \text{Est. BOD, mg}/L \times 8.34\text{ lbs/gal}\\ &= 3.3\text{ MGD} \times 1{,}219\text{ mg}/L \times 8.34\text{ lbs/gal}\\ &= 33{,}549\text{ lbs BOD/day}\end{aligned}$$

2. Calculate the amount of ammonia (NH_3-N) required in pounds per day. Assume an ammonia requirement of 2 pounds NH_3 per 100 pounds BOD.

$$\begin{aligned}NH_3\text{ Required, lbs/day} &= \text{BOD, lbs/day} \times \frac{NH_3\text{-N, lbs}}{\text{BOD, lbs}}\\ &= 33{,}549\,\frac{\text{lbs BOD}}{\text{day}} \times \frac{2\text{ lbs }NH_3\text{-N}}{100\text{ lbs BOD}}\\ &= 671\text{ lbs }NH_3\text{-N/day}\end{aligned}$$

3. Estimate the ammonia (NH_3-N) supplied to the aeration basins in the primary clarifier effluent.

$$\begin{aligned}NH_3\text{ Supplied, lbs/day} &= \text{Flow, MGD} \times NH_3\text{-N, mg}/L \times 8.34\text{ lbs/gal}\\ &= 3.3\text{ MGD} \times 8.36\text{ mg}/L \times 8.34\text{ lbs/gal}\\ &= 230\text{ lbs }NH_3\text{-N/day}\end{aligned}$$

4. Determine the amount of ammonia (NH_3-N) that must be added to the primary effluent.

$$\begin{aligned}NH_3\text{ Added, lbs/day} &= NH_3\text{ Required, lbs/day} - NH_3\text{ Supplied, lbs/day}\\ &= 671\text{ lbs/day} - 230\text{ lbs/day}\\ &= 441\text{ lbs }NH_3\text{-N/day}\end{aligned}$$

NOTE: Effluent NH_3-N concentration is 0.88 mg/*L* which is a satisfactory (possibly a little high) level.

5. Calculate the rotameter setting. The rotameter constant is 5.45 lbs NH_3-N for a 24-hour period for each one percent.

$$\text{Rotameter Setting, \%} = \frac{NH_3\text{-N Added, lbs/day}}{5.45 \text{ lbs } NH_3\text{-N/day/\%}}$$

$$= \frac{441 \text{ lbs } NH_3\text{-N/day}}{5.45 \text{ lbs } NH_3\text{-N/day/\%}}$$

$$= 81\%$$

2.564 Aeration Basic Flow Scheme

Immediately after nutrient addition, the primary clarifier effluent enters the first aeration basin or "contact cell." The wastewater is highly bio-oxidizable and combined with the return sludge (which has been re-aerated) they exert an immediate high oxygen demand upon the aeration system. Figure 2.16, the Simplified Aeration Basic Flow Schematic, is a clear overview of the activated sludge system. The fresh waste is distributed throughout the basin and mixed with return sludge from the adjacent "Return Sludge Reaeration" cell. Together, the return sludge and fresh waste travel in a "plug flow" pattern through nine (9) aeration cells (0.303 MG or 1,150 cu m each) in a serpentine fashion. Assuming an average flow of 3.0 to 3.5 MGD (11,350 to 13,250 cu m/day) and a 35 percent return sludge pumping rate, aeration time is approximately 14 to 16 hours. The mixed liquor leaving the final aeration cell is split and distributed to the two secondary clarifiers. The activated sludge mixed liquor is next separated from the final effluent within the secondary clarifier. The sludge organisms settle within the quiescent (calm) clarifier and are removed from the bottom of the tank while the clear effluent overflows the tank weirs. From the secondary clarifier the secondary effluent passes through a chlorine contact chamber and is chlorinated. If necessary the final effluent is dechlorinated with sodium bisulfide before discharge to the receiving waters. A small portion of the return sludge is continuously wasted. Return sludge that is not wasted enters the return sludge re-aeration basins. Flow of the return sludge within the re-aeration system is also in a "plug flow" pattern. Return sludge within the re-aeration phase is allowed to "rest" for 18 to 20 hours before reentering the contact cell of the aeration system. The trip of a sludge particle that makes the complete loop from the contact cell, through the entire aeration and re-aeration system and back to the contact cell, could take 32 to 36 hours under the previously described operating conditions.

2.565 Activated Sludge System Operation

Brewery wastewaters, as well as many other food processing wastewaters, are highly bio-oxidizable. This means that when activated sludge organisms come in contact with the fresh wastewater, the organisms will immediately start to use the wastewater as a food source. When this happens there is a sudden demand for oxygen by the sludge organisms. Dissolved oxygen (DO) uptake rates in excess of 200 mg O_2/hr/*L* may occur. The aeration basin DO levels might even drop to 0.5 mg/*L* or less. Some believe that when DO levels greater than 5.0 mg/*L* are *NOT* maintained, this will promote the growth of filamentous organisms. This is just one possible cause of filamentous growth. Filamentous organisms are often cited as a possible cause of sludge "bulking." To avoid DO level sags within the first aeration basin or "contact cell," and the associated possibility of sludge "bulking," several design modifications have been made to the basin.

The Contact Cell Aeration Mode is shown within Figure 2.17. This is an enlarged view of the first aeration basin that receives the primary effluent. The view shown here represents what would be seen if you were looking down into a nearly empty aeration basin. A jet-type aeration system that uses Venturi nozzles is the type of aeration system used. Two large submerged basin recirculation pumps collect mixed liquor and pump it into the "liquid" header. Air or oxygen is metered into the "gas" header. When the "liquid" and "gas" pass through the aeration Venturi nozzles simultaneously, a jet action occurs and the gas becomes impinged within the liquid. These aeration basins are not covered. This type of jet aeration system is used within all aeration basins and the capability of using air *OR* oxygen within all of the "gas" headers exists. In most basins where DO requirements can be met with air, standard aeration blowers are used to supply air and satisfy oxygen demands. However, in the contact cell where DO demands are high, oxygen is necessary (pure oxygen is more effective than air because air is only 21 percent O_2). The oxygen is first vaporized from liquid and then metered into the "gas" header within the contact cell. When oxygen is used within the header, *NO AIR* is used simultaneously. Within the "contact cell" special modifications direct the raw primary clarifier effluent and the return activated sludge from the last reaeration basin to within the immediate vicinity of the submerged pump's suction. This is accomplished by piping and duct work that are equipped with flow metering devices. This modification enables the fresh re-aerated return sludge and wastewater to be mixed and quickly distributed throughout the contact cell. With the aid of oxygen, it is possible to maintain minimum DO levels. An on-line DO meter and lab meter are used to monitor the basin and frequent oxygen flow rate adjustments are made. Following "contact" the mixed liquor moves to the aeration basin on the right (in a plug flow fashion) through a submerged flow control gate. The "plug flow" mode of aeration basin flow is used because this type of basin flow (rather than "complete mix") has also been cited as being instrumental in the *PREVENTION* of the growth of filamentous organisms or dispersed growth. Also, this particular aeration scheme has been the most successful mode at this plant for obtaining the required 20/20 BOD/SS effluent.[15]

Aeration basin MLSS levels are run at various levels between 2,000 to 2,800 mg/*L* (85 percent VSS). Many factors dictate the exact MLSS level that is maintained. An example of this is influent organic loading. When very low ogranic loadings occur to the aeration basins, a relatively low MLSS should be maintained to prevent an excessive sludge age from developing. The inverse relationship is also true to a certain degree. Temperature is another factor that greatly influences the MLSS level that should be maintained. The activity (ability to remove carbon) of the sludge organisms within the biomass is highly temperature dependent. An increase in basin temperature of only 10°C (i.e. an increase from 20°C to 30°C) can *DOUBLE* the activity of the biomass. Therefore, during periods of higher summer temperatures, a lighter biomass MLSS can achieve the same organic removals as twice (2×) the biomass under winter operating conditions (temperatures). As the sludge organisms increase their activity as a result of warmer basin temperatures, they also increase the quantities of oxygen required. This means that at high MLSS levels and high basin temperatures, it is often difficult to maintain satisfactory DO levels within the aeration basins. When this happens and aeration capabilities cannot be increased, it often becomes necessary to trim back the MLSS levels until minimum DO levels are achieved again.

The suspended solids levels maintained within the return sludge re-aeration basins often range from 6,000 to 10,000 mg/*L*. This concentration depends on the settling characteris-

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[15] *An effluent with less than 20 mg/L of both BOD and suspended solids.*

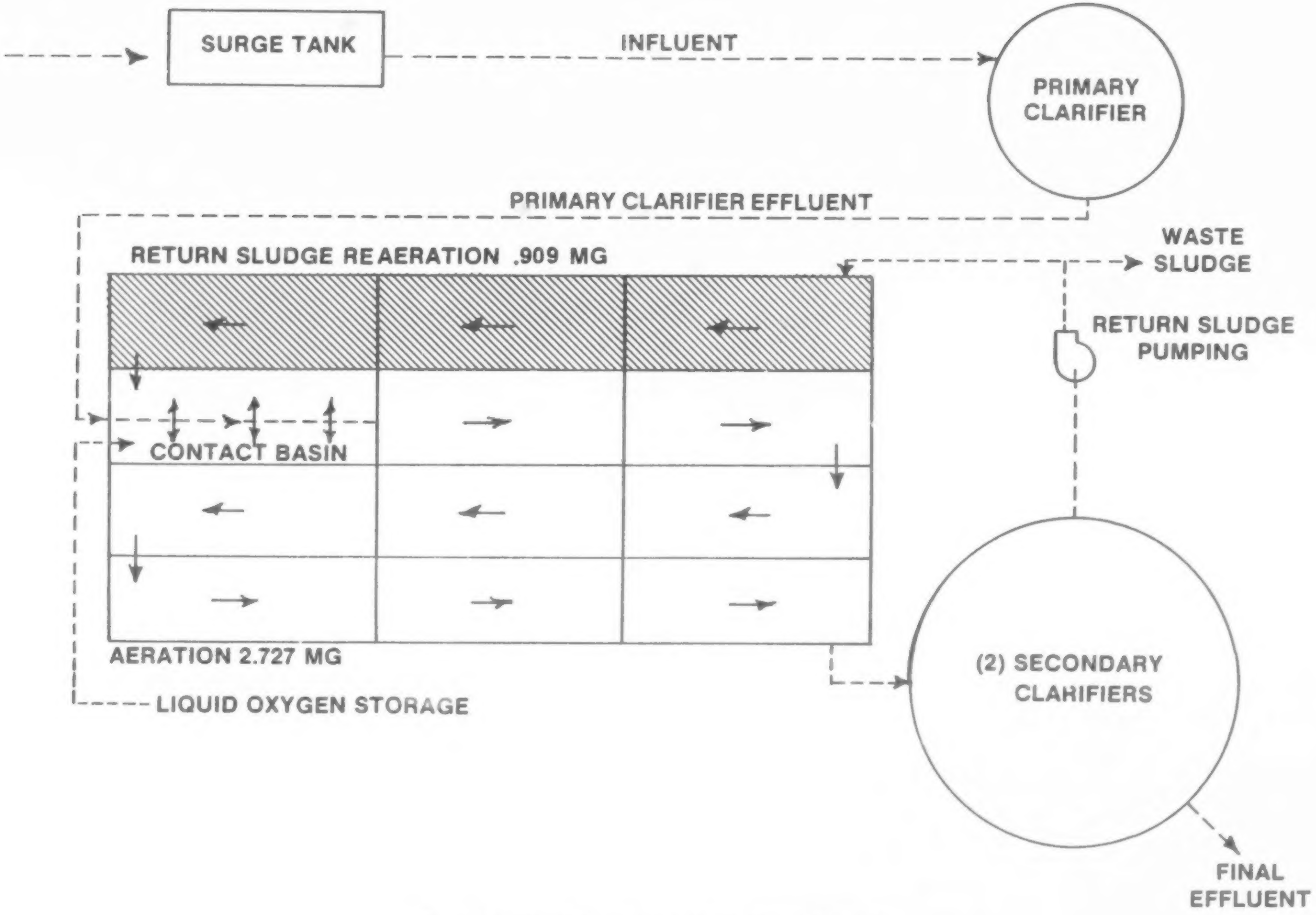

SURGE TANK
INFLUENT
PRIMARY CLARIFIER
PRIMARY CLARIFIER EFFLUENT
WASTE SLUDGE
RETURN SLUDGE REAERATION .909 MG
RETURN SLUDGE PUMPING
CONTACT BASIN
AERATION 2.727 MG
LIQUID OXYGEN STORAGE
(2) SECONDARY CLARIFIERS
FINAL EFFLUENT

Fig. 2.16 Simplified aeration basin flow schematic

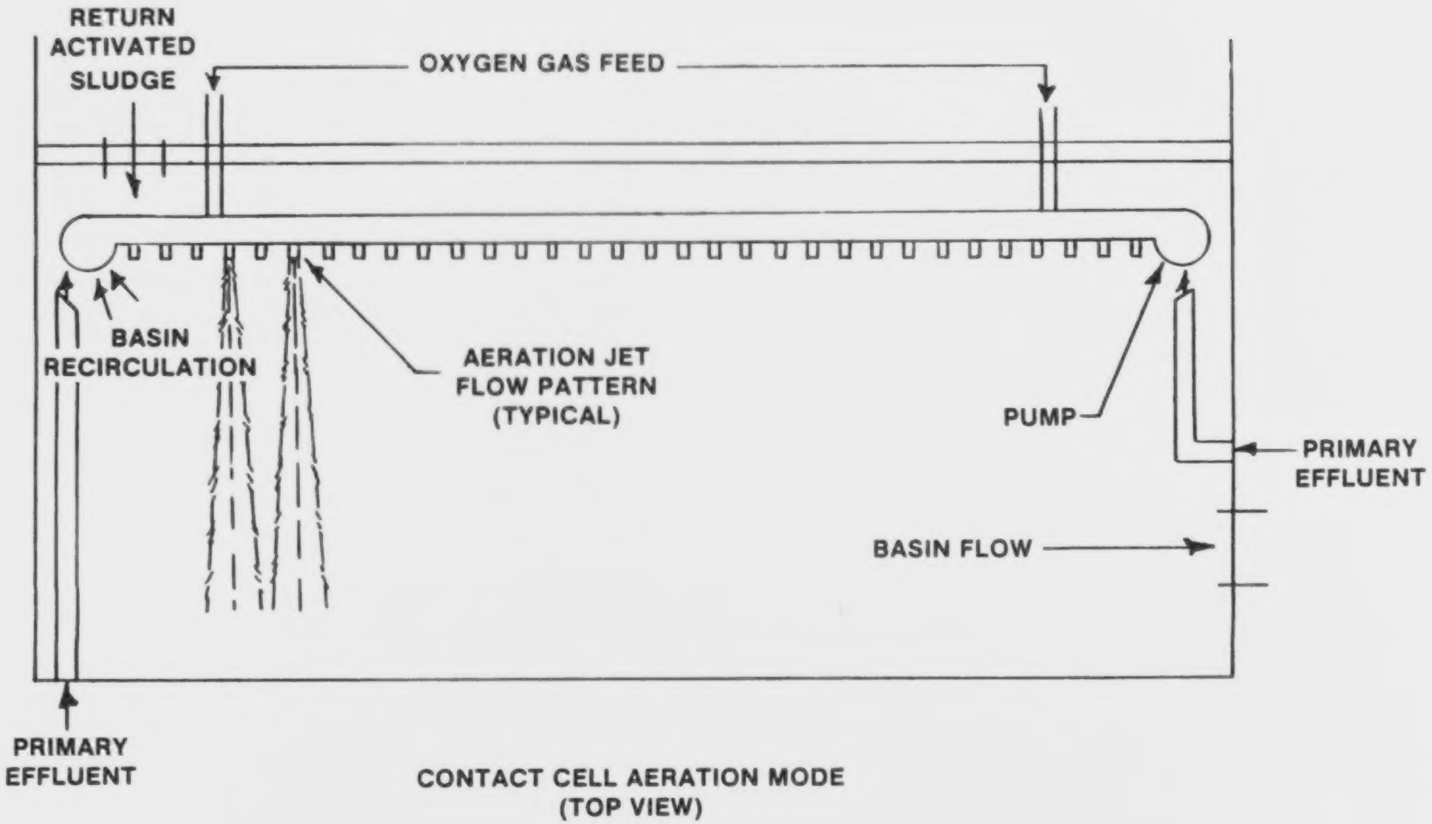

RETURN ACTIVATED SLUDGE
OXYGEN GAS FEED
BASIN RECIRCULATION
AERATION JET FLOW PATTERN (TYPICAL)
PUMP
PRIMARY EFFLUENT
BASIN FLOW
PRIMARY EFFLUENT
CONTACT CELL AERATION MODE (TOP VIEW)

Fig. 2.17 Contact cell aeration mode (top view)

tics of the sludge and the operation of the secondary clarifiers. Return sludge rates are adjusted to maintain a sludge blanket between 12 to 18 inches deep (30 to 45 cm) within the secondary clarifier. Numerous blanket depth measurements (with a "thief" type sampler) are made to control the blanket depth. The goal is *NOT* to build a *DEEP* blanket (that leaves sludge within the clarifiers for a long period of time) *OR* to pump the blanket levels *TOO LOW* and then pump only dilute sludge into the return sludge re-aeration basins. An on-line suspended solids meter is used to monitor return sludge suspended solids levels and to aid with this determination. Also, grab samples of the secondary clarifier influent are taken frequently to measure sludge settling rates and sludge volume indices (SVIs). Once again, just as the relationship between temperature and basin DO levels dictates maximum MLSS levels, the settling characteristics of the sludge within the secondary clarifier may also dictate the maximum MLSS level that can be maintained under aeration. To control clarifier sludge blanket depth, return sludge pumping rates can be increased only to a certain point (about 50 percent), and after that further increases in return rates are not beneficial. This is because the additional return that is pumped back through the re-aeration and aeration system ultimately comes back into the clarifier and causes a high hydraulic loading. This increased hydraulic loading into the clarifier can cause the characteristically light fluffy sludge to become stirred up and possibly bulk. If the sludge settling characteristics are poor (high SVI) and increasing return sludge pumping rates do not control sludge blanket depths, again MLSS levels must be trimmed back.

Other commonly used activated sludge operational control factors such as the food to microorganisms ratio (F/M), mean cell residence time (MCRT) and sludge age, are very difficult to us as the *SOLE* determining factor to direct sludge wasting on a day to day basis. These factors can be very useful as plant design figures or they can be used to determine desirable operating ranges. However, to calculate these factors and adjust sludge wasting rates or to attempt to adjust MLSS levels on a daily basis "shooting" at a specific *F/M SET POINT* becomes impossible. When highly fluctuating organic loads enter a plant it is very difficult to waste or build MLSS rapidly enough (within 24 hours) to meet a specific set point. Instead, select a proper *MLSS* level *SET POINT* which actually results in an F/M, MCRT or sludge age value that floats in the vicinity of what would approximate a desirable "factor" range! In reality there are many interrelated and independent factors that influence plant operation. These factors include basin DO levels that can be maintained, sludge settling characteristics, effluent quality and many other factors dictate what MLSS level can be maintained. This proper MLSS level must be determined experimentally by *SLOWLY* adjusting the MLSS level together with careful observation of plant behavior. Ultimately a proper MLSS *SET POINT* can be determined and used to control sludge wasting activities. However, you must realize that this "proper MLSS set point" may have to be adjusted when influent characteristics change and when seasonal changes occur.

As previously described, all sludge that is not wasted flows into the re-aeration portion of the plant. There are numerous benefits from return sludge re-aeration. A list of some of the advantages is as follows:

1. Basic math indicates that if nine aeration basins are maintained at a MLSS of 2,000 mg/*L*, then the addition of only three return sludge re-aeration basins (*ALL* basins equal 0.303 MG or 1,150 cu m) at a SS level of 6,000 mg/*L* (return sludge concentration) will *DOUBLE* the available biomass within the activated sludge system. (9 aeration × 2,000 mg/*L* = 3 re-aeration × 6,000 mg/*L* or double initial capacity.)
2. During periods of high organic loading, the re-aeration phase allows adequate "rest" time for the sludge organisms to metabolize **ad**sorbed and **ab**sorbed BOD.
3. If a poison or toxic substance should enter the plant (heavy metals, pH or temperature shift) only a small portion of the biomass will be destroyed. The plant can recover quickly and be back on line within a short period of time (again achieving satisfactory BOD removal).
4. The "rest" period within re-aeration seems to condition the sludge so that it will readily accept new influent loading and consistently obtain high BOD removals (+98 percent).

2.566 *Sludge Wasting*

An example of a sludge wasting calculation is included. The major basis of the calculation is that sludge wasting will be done continuously for a 24-hour period with the *GOAL* being a desired *MLSS "SET POINT."* Every 24 hours all of the data is reviewed and a new sludge wasting rate is implemented.

The following illustrates the wasting formula calculation. As a quick indication of influent organic strength, a total organic carbon (TOC) measurement is used to project BOD loading.

SAMPLE DATA: **Item**	**Data**
Final Aeration Cell MLSS	2,420 mg/*L*
Primary Effluent, 24-hour Composite Sample, TOC	554 mg/*L*
Desired MLSS set point	2,200 mg/*L*
Return Sludge (waste) SS	7,160 mg/*L*
Estimated Flow for the Next 24 hours	3.3 MGD

Volumes and Assumptions

1. Volume of each aeration cell 0.3 MG.
2. Nine aeration cells, total aeration volume 2.7 MG.
3. Solids in secondary clarifiers are equal to 15 percent of the solids within the aeration basins.
4. MLSS of final aeration basin is representative of the MLSS of all the aeration basins. 9 × final aeration basin MLSS = total aeration solids.
5. Yield factor = 0.5 lbs MLSS solids produced/lb BOD removed.
6. Estimate primary effluent flow from recent records and actual flow data for first 8 to 10 hours of the day. Take into consideration whether the sludge wasting system is in operation.
7. Conversion factor = Yield × BOD:TOC ratio

   1.1 = 0.5 × 2.2

SAMPLE WASTING FORMULA CALCULATIONS

1. Calculate the solids in the system in pounds. Since solids in the secondary clarifiers are 15 percent of the solids in the aeration basins, multiply the solids in the aeration basins by 1.15.

$$\begin{aligned}\begin{matrix}\text{Solids in}\\ \text{System, lbs}\end{matrix} &= \begin{matrix}\text{Aeration}\\ \text{Volume, MG}\end{matrix} \times \begin{matrix}\text{Final Aeration}\\ \text{Cell MLSS, mg}/L\end{matrix} \times 8.34\,\frac{\text{lbs}}{\text{gal}} \times 1.15\\ &= 2.7 \text{ M Gal} \times 2420 \text{ mg}/L \times 8.34 \text{ lbs/gal} \times 1.15\\ &= 62{,}668 \text{ lbs}\end{aligned}$$

2. Estimate the solids produced in the system in pounds per day. Assume 1.1 pounds of solids are produced per pound of TOC.

$$\begin{aligned}\text{Solids Produced, lbs/day} &= \frac{1.1 \text{ lbs solids/day}}{1 \text{ lb TOC/day}} \times \text{TOC, lbs/day}\\ &= 1.1 \times \text{Flow, MGD} \times \text{TOC, mg}/L \times 8.34 \text{ lbs/gal}\\ &= 1.1 \times 3.3 \text{ MGD} \times 554 \text{ mg}/L \times 8.34 \text{ lbs/gal}\\ &= 16{,}772 \text{ lbs solids/day}\end{aligned}$$

3. Determine the desired pounds of solids in the system based on a MLSS set point of 2,200 mg/*L*. Assume solids in the secondary clarifiers are 15 percent of the solids in the aeration basins (multiply by 1.15).

$$\begin{aligned}\text{Desired Solids in System, lbs} &= \text{Aeration Volume, MG} \times \text{MLSS Set Point, mg}/L \times 8.34 \frac{\text{lbs}}{\text{gal}} \times 1.15\\ &= 2.7 \text{ M Gal} \times 2{,}200 \text{ mg}/L \times 8.34 \text{ lbs/gal} \times 1.15\\ &= 56{,}971 \text{ lbs}\end{aligned}$$

4. Calculate the sludge wasting amount in pounds per day.

$$\begin{aligned}\text{Sludge Wasting Amount, lbs/day} &= \frac{(\text{Solids in System, lbs} - \text{Desired Solids in System, lbs})}{\text{Waste During 1 day}} + \text{Solids Produced, lbs/day}\\ &= \frac{(62{,}668 \text{ lbs} - 56{,}971 \text{ lbs})}{1 \text{ day}} + 16{,}772 \frac{\text{lbs}}{\text{day}}\\ &= 5{,}697 \text{ lbs/day} + 16{,}772 \text{ lbs/day}\\ &= 22{,}469 \text{ lbs/day}\end{aligned}$$

NOTE: If the sludge wasting rate is negative, the MLSS is too low. Reduce the existing wasting rate by 10 to 15 percent. Some operators shut off the waste when negative values are obtained, but many operators try to avoid drastic changes in wasting rates by adjusting the existing wasting rate up or down by no more than 10 to 15 percent each day.

5. Determine the sludge wasting rate in MGD and GPM.

$$\begin{aligned}\text{Sludge Wasting Rate, MGD} &= \frac{\text{Sludge Wasting Amount, lbs/day}}{\text{Waste Sludge SS, mg}/L \times 8.34 \text{ lbs/gal}}\\ &= \frac{22{,}469 \text{ lbs/day}}{7{,}160 \text{ mg}/L \times 8.34 \text{ lbs/gal}}\\ &= 0.376 \text{ M gal/day}\end{aligned}$$

$$\begin{aligned}\text{Sludge Wasting Rate, GPM} &= \frac{376{,}000 \text{ gal/day}}{1{,}440 \text{ min/day}}\\ &= 261 \text{ GPM}\end{aligned}$$

Waste sludge is first pre-thickened in dissolved air flotation (D.A.F.) units and mixed with primary sludge in the sludge holding tanks. Water is evaporated from the separated sludge mixture within the sludge drying plant and the product is currently marketed as a high vitamin B-12, high protein, animal feed supplement.

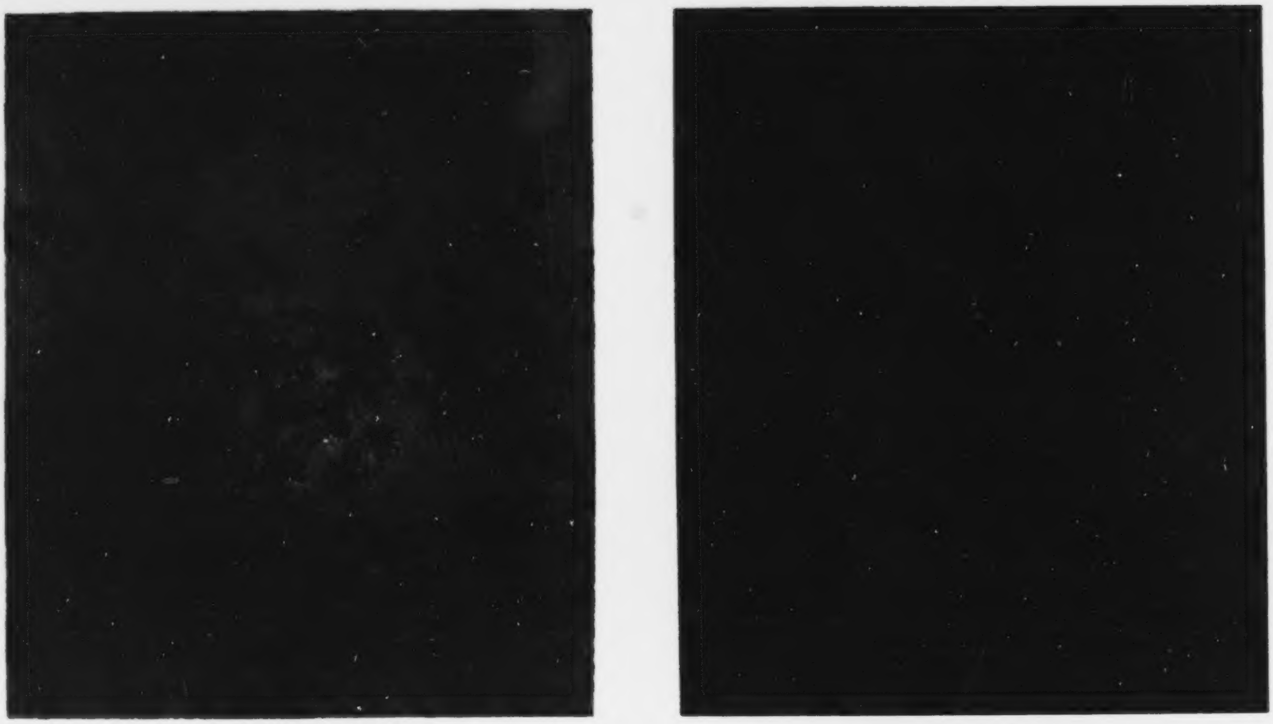
One last item that should be covered along with aeration basin control is the subject of aeration basin foam. At all times foam is present on the basin surfaces. Foam is a natural part of the biomass. A dark, greasy looking foam is the sign of an old sludge age while a white, clear foam is indicative of a young sludge age. Large quantities of foam can sometimes cause operational problems if the foam does not stay within the basins. Excessive foam can be caused by large quantities of detergents within the waste stream or some brewery materials such as yeast. Control of this foam can be achieved by: (1) decreasing air flow to the aerators, (2) by the use of chemical surfactants, or (3) by water sprays aimed to physically collapse the foam. A novel approach to foam control involves overflowing the aeration basin into a small side basin, letting the foam collapse and then wasting this foaming material from the plant.

2.567 Filamentous Organisms

Within brewery wastewater treatment plants, often the number one operational problem is the control of filamentous organisms (Fig. 2.18). Often sludge "bulking" is related to a filamentous bacteria by the name of *SPHAEROTILUS NATANS.* To blame all sludge bulking on this *ONE* type of filamentous organism is a misconception. In reality there are about 10 different types of filamentous organisms that can become predominant within *BREWERY* activated sludge and cause sludge settling problems. To a certain degree there is a relationship between the different filamentous organisms and specific operating conditions. Therefore, in some cases, if the type of filamentous organism can be identified, the causative operating condition can also be determined and rectified. However, this approach is usually not practical. To begin with, specific filamentous organism identification requires 500X — 1,000X power microscope. Also, even if the specific filament can be identified, the literature relating filament type to causative condition is somewhat limited.

A more successful approach to filamentous organisms management, as reported within the literature is described as follows: (It should be noted that only *SOME* of the techniques described have been used at the plant described here.)

1. Determine if filamentous organisms are the true culprit. This can usually be done by examining a sludge sample with a relatively inexpensive microscope. The filamentous organisms look like fine "hairs" or "wires" extending out of the sludge floc particles or they can be found in the liquor floating free. Some filaments are always present, but if they appear to be 20 percent of the biomass or more, they could be causing settling problems.
2. A "short term" corrective step is often necessary to halt immediate "bulking." Many process adjustments can be done to bring the filaments under control:
   a. Careful polymer or chemical ($FeCl_3$) dosage to prevent SS loss within the secondary clarifiers.
   b. Excessive sludge wasting to remove filamentous organisms from the system.
   c. Chemical dosage of the return sludge with oxidants such as H_2O_2 (0.1 lb H_2O_2/1 lb. VSS) or Cl_2 (3 to 5 lbs Cl_2/1000 lbs VSS).
3. Develop a "long-term" control program to correct operational problems and to prevent the recurrence of filamentous organisms. A list of common causes of filamentous "bulking" is as follows:
   a. Low DO levels within aeration basins and secondary clarifiers (this is often a *RESULT* of a high F/M ratio, although the F:M ratio alone is not necessarily the problem).



1. Typical brewery activated sludge, few filaments

2. Brewery activated sludge, some filaments

3. Typical highly filamentous sludge

Fig. 2.18 Filamentous organisms (100 × magnification)

b. A lack of adequate nutrients (nitrogen or phosphorus) or trace minerals within the influent.

c. The presence of high levels of sulfur within the influent.

d. Low F/M levels within aeration system (less than 0.2).

e. Large fluctuations within the plant influent organic loading.

Many of these problems can be overcome by implementing operational changes and by engineering design changes. At the wastewater treatment plant under examination here, many changes have been made to control the growth of filamentous organisms. Experimentation has revealed that the dissolved oxygen concentration (DO) is the most influential factor that affects filamentous organism growth within this plant. Since some filamentous organisms are often desirable (to maintain floc structure), a desired *DO LEVEL SET POINT* is used to *ADJUST FILAMENT CONCENTRATIONS*. Over a long period of time, experience has shown that filamentous organism concentrations can be adjusted by adjusting "contact" cell DO levels. *AN INCREASED DO LEVEL* (5 to 10 mg/*L*) will yield *A DECREASE IN FILAMENTOUS ORGANISMS. A DECREASED DO LEVEL* (1 to 3 mg/*L*) will result in an *INCREASED NUMBER OF FILAMENTOUS ORGANISMS.*

2.568 Laboratory Testing

Only a small portion of the testing within a brewery wastewater treatment plant is devoted to "permit" monitoring requirements. The majority of the laboratory time is spent obtaining test data that is required to assist in making process control adjustments. Numerous MLSS measurements are made to evaluate sludge wasting needs and sludge settling characteristics. Plant loading data is updated daily by the use of Total Organic Carbon (TOC) analysis. Nutrient concentrations are measured at several locations within the plant to assist with nutrient addition calculations. Both 24-hour composite samples and grab samples are used to obtain representative data. Microphotographs (Fig. 2.18) of sludge samples from several locations within the aeration system serve as a permanent record of microorganism diversity and relative filamentous organism concentrations. Many additional quantitative and qualitative tests are performed and the results are recorded. This data, along with numerous other measurements and evaluations recorded throughout the wastewater treatment plant serve as the basis for mapping out operational control strategies and are indispensable.

2.569 Recordkeeping

Every wastewater treatment plant is different and requires different types of testing and record keeping. There is no substitute for well organized laboratory data and operational log sheets. The extreme value of this information cannot be over emphasized. Well recorded data can serve as a quick update to an operator coming on shift or it may be graphed, charted, or tabulated to indicate more clearly overall trends. Proper use and analysis of records have allowed the operators of plants treating brewery wastes to produce a high quality effluent.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 97.

2.56A Why are primary clarifiers not very effective in removing BOD from brewery wastes?

2.56B Where are nutrients added and how are nutrients added when treating brewery wastes?

2.56C What factors influence the MLSS level in the aeration basins?

2.56D How is the sludge wasting rate determined?

2.56E How can filamentous "bulking" be controlled in activated sludge plants treating brewery wastes?

2.57 Food Processing Wastes

This section discusses how to treat wastewaters from two different types of food processing wastes. Treatment of artichoke wastewater and dairy wastes are presented by two operators who actually treat these wastes on a day-to-day basis. Almost all of the foods we eat (fruits, vegetables, fish, meats, dairy products) produce wastewaters when they are processed for consumption. Treatment of these wastewaters may be unique for each food, but the basic principles of pretreating the wastewater to produce an environment suitable for activated sludge treatment are similar.

2.570 Treatment of Artichoke Wastewater by Peter Luthi

Processing of artichokes in California is a year round operation with a major peak during the months of March, April and May and a minor peak in September, October and November. The fact that some wastewater is generated all year round makes the operation of an activated sludge system possible at this pretreatment facility (Fig. 2.19). The effluents from the activated sludge plant which treats high strength wastewater, the flotation unit which treats medium strength wastewater, and cooling water with a low BOD load are all discharged into the sewer for final treatment by the municipal wastewater treatment plant.

Wastewaters from the artichoke processing plant are segregated according to BOD strength and only the highest BOD portion of the wastewater is treated by the activated sludge system (Fig. 2.19). Primary objectives of the activated sludge treatment process are to:

1. Treat the high strength (high BOD) waste to acceptable levels with a minimum of input (energy, labor, dollars) and a minimum of waste sludge produced, and
2. Produce a treated effluent that is discharged to a municipal treatment plant that meets the following discharge limits:
   a. BOD <500 mg/*L*,
   b. Suspended solids <500 mg/*L*, and
   c. pH within a range of 6 to 9.

BOD strength of the wastewater treated varies between 1,000 and 15,000 mg/*L* with a pH of around 4.5 (from the use of vinegar and citric acid in the process). Volume of high strength BOD water ranges from 1,500 gal/week to 15,000 gal/week (5.7 to 57 cu m/week) during the peak season.

2.571 Pilot Project

The unusually high and widely fluctuating BOD levels of the waste required that the feasibility of an activated sludge system be studied on a pilot project. An activated sludge system

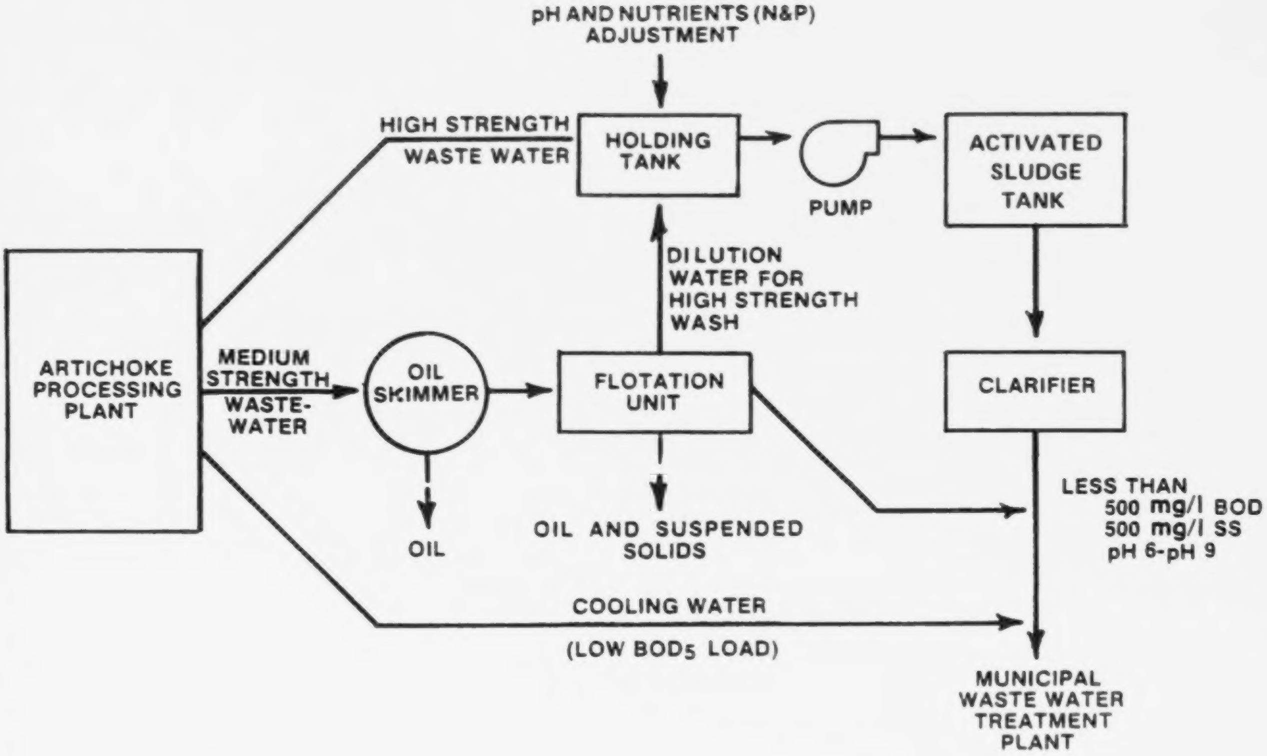

pH AND NUTRIENTS (N&P)
ADJUSTMENT
HIGH STRENGTH
WASTE WATER
HOLDING
TANK
PUMP
ACTIVATED
SLUDGE
TANK
DILUTION
WATER FOR
HIGH STRENGTH
WASH
ARTICHOKE
PROCESSING
PLANT
MEDIUM
STRENGTH
WASTE-
WATER
OIL
SKIMMER
FLOTATION
UNIT
CLARIFIER
OIL
OIL AND SUSPENDED
SOLIDS
LESS THAN
500 mg/l BOD
500 mg/l SS
pH 6-pH 9
COOLING WATER
(LOW BOD5 LOAD)
MUNICIPAL
WASTE WATER
TREATMENT
PLANT

Fig. 2.19 Artichoke activated sludge pretreatment facility

with extended aeration using mean cell residence times up to 15 days was chosen. As much as 90 to 95 percent BOD removal could be achieved if the influent BOD was kept below 6,000 mg/*L*. Higher influent BODs resulted in lower effluent quality. Medium strength wastewater is therefore used to dilute the influent.

To accumulate some operating data during the pilot project, the following analyses were performed on a daily basis:

1. Influent and effluent COD and suspended solids,
2. Mixed liquor suspended solids,
3. pH of influent, mixed liquor and effluent,
4. Dissolved oxygen, and
5. SVI

COD rather than BOD was chosen for its relatively easy and fast analysis. A graph showing 15-day moving average influent COD, mixed liquor, suspended solids, moving F/M ratio, effluent COD and suspended solids was drawn and kept up daily to find the best operating guidelines. Fifteen-day moving averages for influent COD and F/M ratio were computed to reduce the effect of fluctuating daily results.

2.572 *Daily Operational Procedures*

Through trial and error, and after several upsets over a nine-month period, it was readily visible from the graph and data accumulated that acceptable results (less than 500 mg/*L* BOD and suspended solids) were obtainable when the F/M ratio was kept between 0.08 to 0.28 pounds BOD/day/pound MLVSS.

Daily influent and effluent COD and pH, mixed liquor and effluent suspended solids analyses are performed. Also, determing the SVI on a daily basis is helpful in detecting changes in the settling characteristics of the activated sludge. Sludge volume indeces were, however, generally higher than data given in literature for municipal treatment plants.

Nutrients (N and P, in the form of ammonium phosphate fertilizer) were initially added in batches on a daily basis. However, a continuous addition directly into the in-feed line used later on proved much more reliable and provided for a smoother operation. Lack of sufficient nutrients was responsible for bad settling characteristics in several cases. If the SVI increases and lack of nutrients is suspected, a look at the sludge under the microscope should be taken. The presence of filamentous bacteria will confirm the suspicion. Sufficient amounts of nutrients proved to be quite important and upsets caused by their lack took a long time to remedy. No provision for chlorinating the return sludge exists. No adverse effects were observed by the addition of too much nitrogen and phosphorus.

To keep influent COD concentration as steady as possible on a day-to-day basis, dilution with medium strength wastewater is used when needed.

The fluctuating concentrations of the influent COD make it necessary to keep the DO level in the aerator between 4.0 and 6.0 mg/*L*. Rapid changes occur sometimes and can drop DO levels to as low as 2.0 mg/*L* in a matter of hours. Therefore, keeping levels at 4.0 to 6.0 mg/*L* assures that the DO does not drop below the critical 2.0 mg/*L*.

Effluent pH monitoring shows that when effluent pH drops below 6.5 it is necessary to adjust the influent pH to between 5.5 and 6.5. This is done with granular sodium hydroxide added to the holding tank. At times of low feed rates, however, the system is able to tolerate the normal influent pH of 4.2 to 4.8 and only occasionally are adjustments necessary.

Influent levels vary from 4,300 gal/day to 8,600 gal/day (16 to 32 cu m/day). Levels higher than 8,600 gal/day (32 cu m/day) produce turbulence in the clarifiers with accompanying solids loss in the effluent. Mixed liquor solids vary from 3,000 to 4,500 mg/*L*. Influent volume is the most important variable used to control the system. By increasing or reducing the volume, the F/M ratio can be increased or decreased more gradually or kept at one level when influent COD concentration changes. In anticipation of heavy production times and coinciding larger amounts of wastewater, mixed liquor solids are allowed to build up to 4,500 mg/*L* and the F/M ratio increases which allows treatment of larger volumes with higher concentrations of COD. Sludge must now be wasted on a daily basis to keep the aerator solids level (MLSS) at 4,500 mg/*L*. Waste sludge is disposed of on land.

Immediately following heavy production, sludge is wasted at an increased rate to reduce mixed liquor solids to 3,000 mg/*L* to avoid starvation of the system now that COD concentration and waste volume are dropping. During times of low production the F/M ratio is reduced to around 0.08 lbs BOD/day/lb MLVSS. At this level of subsistence, when influent BOD level and feed rate are at their lowest, the effluent produced is of a lower quality. More solids than usual are being carried away with the effluent and sludge wasting only has to be done on an occasional basis. However, the primary objectives of reducing effluent BOD and suspended solids levels below 500 mg/*L* can still be achieved.

2.573 *Treatment of Dairy Wastes* by Ralph L. Robbins, Jr.

Dairy wastes can be treated by the various modes of the activated sludge process. Many dairy waste treatment plants have the designed flexibility to treat by either:

1. Extended aeration,
2. Contact stabilization, or
3. Step-feed aeration.

On the basis of actual operating experience and analysis of influent, plant and effluent samples, the extended aeration mode appears to work best for some plants.

2.574 *Plant Influent*

Dairy wastewaters are comprised of production materials such as lactose, calcium lactate and protein hydrolysates. The sanitary facilities at many plants are separate from the industrial dairy wastes and do not enter the wastewater stream to the treatment facility. Thus chlorination of the effluent is not necessary. The influent averages a BOD loading of 3,000 lbs per day (1,360 kg/day) and a total solids level of approximately 3,500 lbs per day (1,590 kg/day). The treatment facility (Fig. 2.20) operates throughout the entire year with little change of temperature in the aeration tanks. The effluent temperature does not fall below 60°F (15°C) year round, thus providing for a stable operation all year.

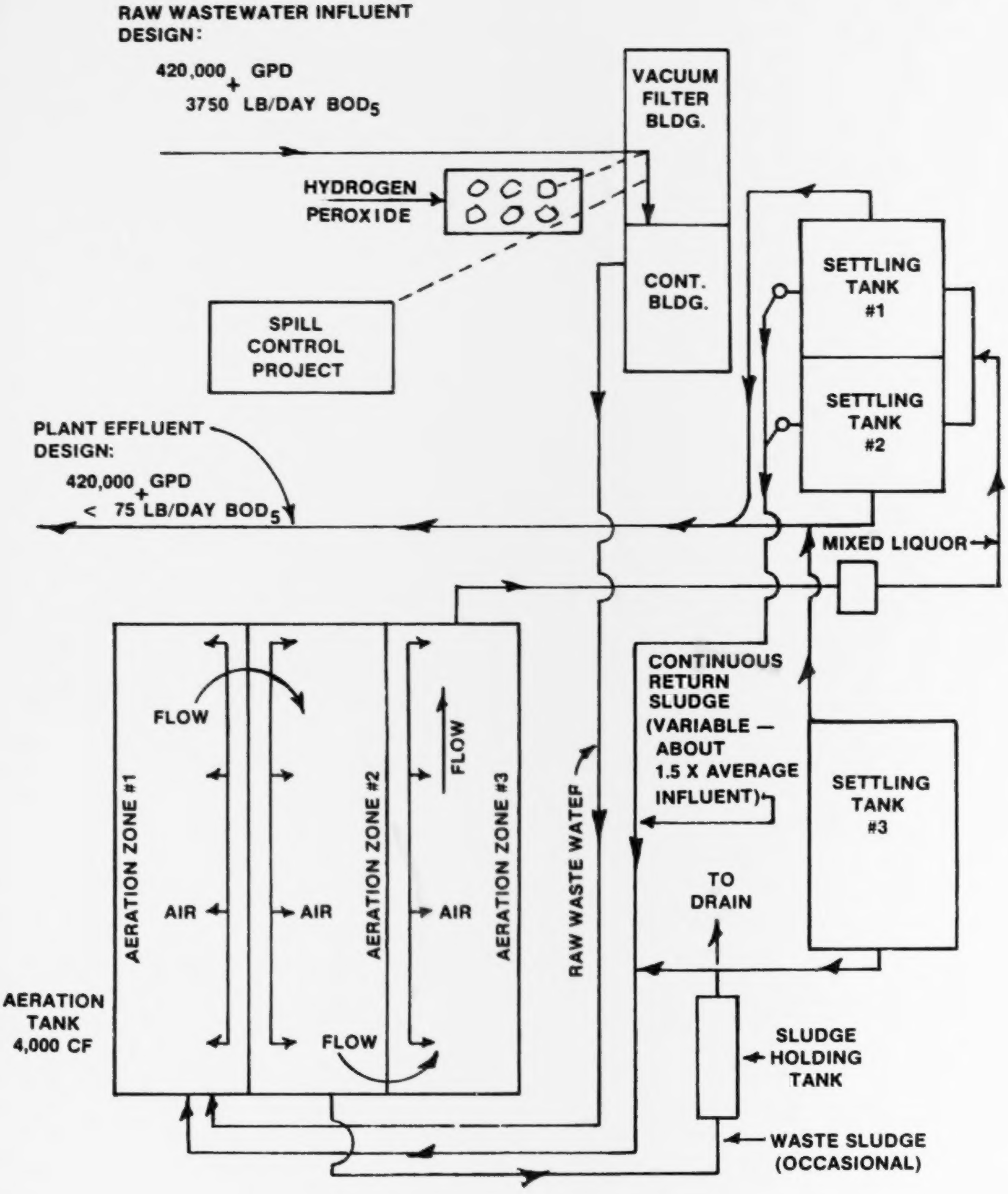

RAW WASTEWATER INFLUENT DESIGN:
420,000 + GPD
3750 LB/DAY BOD5
VACUUM FILTER BLDG.
HYDROGEN PEROXIDE
CONT. BLDG.
SPILL CONTROL PROJECT
SETTLING TANK #1
SETTLING TANK #2
PLANT EFFLUENT DESIGN:
420,000 + GPD
< 75 LB/DAY BOD5
MIXED LIQUOR
CONTINUOUS RETURN SLUDGE (VARIABLE — ABOUT 1.5 X AVERAGE INFLUENT)
SETTLING TANK #3
FLOW
FLOW
AERATION ZONE #1
AERATION ZONE #2
AERATION ZONE #3
AIR
AIR
AIR
RAW WASTE WATER
TO DRAIN
AERATION TANK 4,000 CF
FLOW
SLUDGE HOLDING TANK
WASTE SLUDGE (OCCASIONAL)

Fig. 2.20 Dairy waste activated sludge treatment facility

2.575 *Operation*

Aeration tanks may be operated in the extended aeration mode. Some dairy wastes require at least 18 hours aeration time in the tanks. Up to 80 percent of the BOD load can be reduced in the first tank with the other two tanks treating the remaining 20 percent. For this reason the diffuser capability in the first tank should be twice that of the other two tanks.

The mixed liquor suspended solids level in the aeration tanks are kept at a high level of 1 percent or 10,000 mg/*L*. This high level of MLSS is necessary to prevent process upsets caused by shock organic loadings. Extra air capacity is necessary in case of shock organic loadings in order to keep aeration tank DO levels between 2 to 6 mg/*L*.

Settling tank detention times can be as long as 8 hours. Activated sludge is recirculated to the aeration tanks at a rate of 1½ to 2 times the plant influent rate.

Vacuum filters are used to dewater the sludge. Lime and ferric chloride are added for flocculation of the waste sludge before filtering. The sludge cake runs from 20 to 30 percent dry solids. The waste sludge cake is disposed of at a sanitary landfill site.

2.576 *Plant Effluent*

Plant effluent is monitored daily by plant personnel. Analytically the BOD, SS, COD, phosphorus, nitrate, nitrite and total nitrogen are monitored.

2.577 *Operational Techniques for Upgrading Effluent*

Problems can develop with milk protein breakdown. The addition of 50 mg/*L* of anhydrous ammonia can produce a complete breakdown of milk protein in the aeration tanks. Activated carbon can help in many areas, including odor control, removal of phosphate, media for extra bacteria growth in the aeration tanks and an aid in flocculation and settling in the clarifiers.

A fermentor can be used to grow commercial bacteria for injection into aeration tanks during times of bacteria kill due to shock loadings from major spills in the production area. Installation of a system for the addition of hydrogen peroxide for odor control and additional oxygen during times of shock loadings can be helpful.

A spill control system which diverts major spills into a pretreatment holding tank for pH adjustment and pre-aeration before being blended into the main aeration tanks can be used if there is adequate warning.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 97.

2.57A How are high strength artichoke waste influents (BOD >6,000 mg/*L*) adjusted before being treated by the activated sludge process?

2.57B Why were 15-day moving averages computed and plotted for artichoke influent COD and F/M ratio?

2.57C What chemical can be used to provide nutrients for the treatment of artichoke wastes?

2.57D Why might the chlorination of the effluent from a dairy waste treatment plant not be necessary?

2.57E Why are high levels of MLSS (10,000 mg/*L*) kept in aeration tanks that treat dairy wastes?

PETROLEUM INC

2.58 **Petroleum Refinery Wastes** by Cal Davis

2.580 *Refinery Wastewater Characteristics*

Three main compounds, ammonia, phenols and sulfide, are found in petroleum refining wastewater and can be treated very effectively by the activated sludge process.

Influent flows can vary both in rate and contaminant concentration, very rapidly and without notice. Waste treatment plants with holding ponds can control hydraulic loadings, but not always BOD loadings. To some extent hydraulic loading can be used to control BOD loading with the MLVSS remaining constant in the aeration basin. In the event of a shock load, a hydraulic loading change would be the first corrective step.

2.581 *Activated Sludge Process*

Understanding and monitoring the activated sludge process is important in treating petroleum refining wastewater. Recognizing that each plant operates differently, most petroleum treatment activated sludge units (Fig. 2.21) operate on extended aeration mode with MCRTs up to 30 days in order to maintain the nitrification population necessary to oxidize ammonia. The minimum MCRT for good nitrification seems to be 20 days.

2.582 *Frequency of Sampling and Lab Tests*

Wastewater from a refinery can change in flow rate and waste concentration very suddenly. Certain tests must be run each shift while others can be run daily. Tests that need to be run each shift at the treatment plant include DOs, temperature, pH, sulfide, phenols, ammonia, and 30-minute settleability. During upset conditions these tests need to be run at least twice a shift. Tests that need to be run each day include TOC or COD, BOD, MLTSS, MLVSS, recycle sludge TSS, ammonia, phenols, pH, PO_4 and oil.

2.583 *Operational Procedures*

When you come on duty after a shift change, visually inspect the activated sludge process, and review the log book and lab sheet for any changes in influent rates or concentrations. Check the following items: hydraulic loading, DOs, aeration basin, MLTSS and MLVSS, pH, temperature of influent, sludge recycle rate and clarifier loading. For comparison purposes measure sludge settleability and also calculate the SVI and F/M ratio. Under normal conditions DOs are 1.5 to 2.0 mg/*L*, pH from 6.8 to 7.0, and phenols, ammonia and sulfide are nil.

2.584 *Response to Sulfide Shock Load*

If a check of the activated sludge system shows DOs less than 0.5 mg/*L*, pH of 5.6, aeration basin turning a light color, and phenols showing in effluent, then a sulfide shock is indicated. Testing may show no phenols in influent stream since

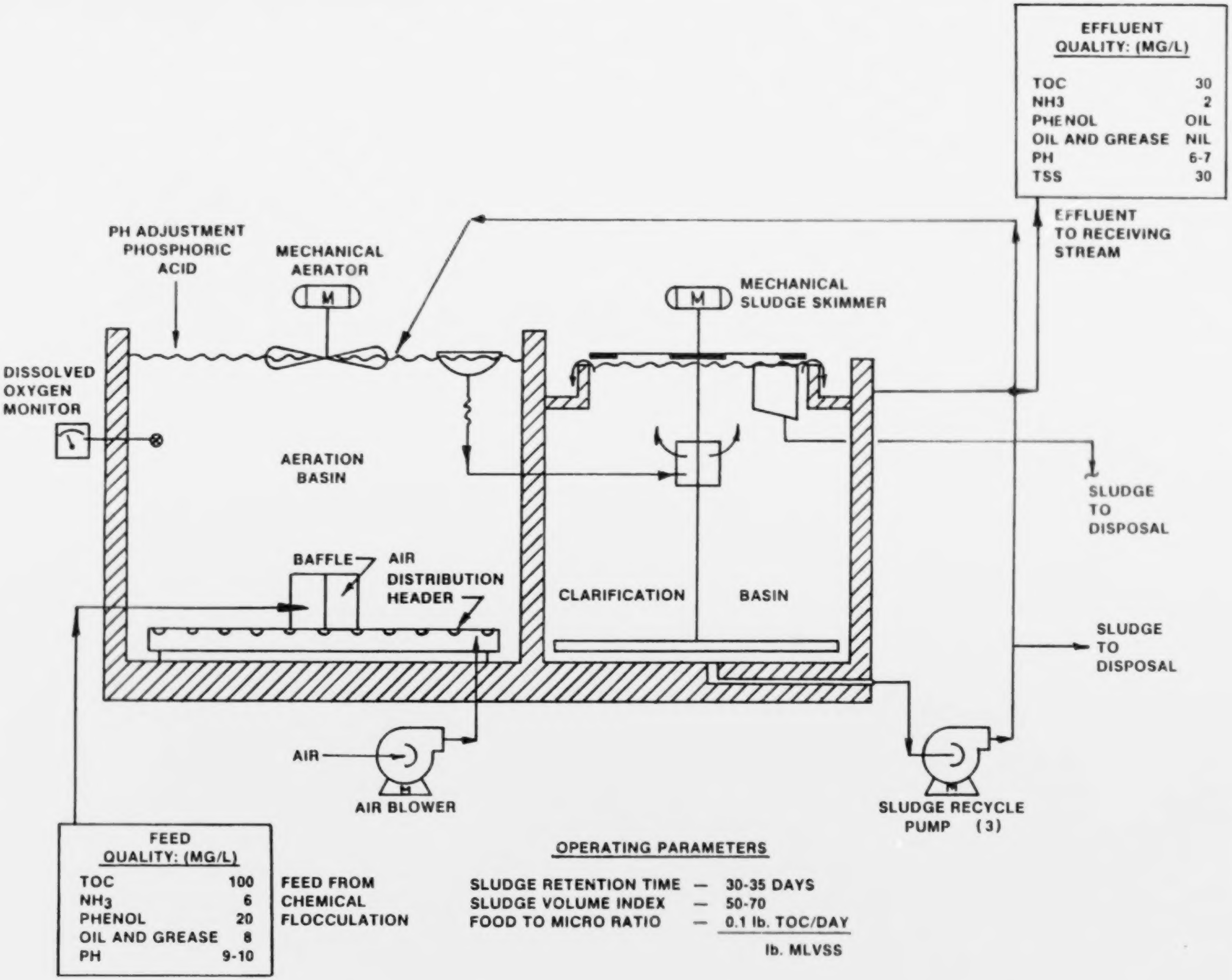

EFFLUENT QUALITY: (MG/L)
TOC 30
NH3 2
PHENOL OIL
OIL AND GREASE NIL
PH 6-7
TSS 30
EFFLUENT TO RECEIVING STREAM
PH ADJUSTMENT PHOSPHORIC ACID
MECHANICAL AERATOR
M
MECHANICAL SLUDGE SKIMMER
M
DISSOLVED OXYGEN MONITOR
AERATION BASIN
SLUDGE TO DISPOSAL
BAFFLE
AIR DISTRIBUTION HEADER
CLARIFICATION
BASIN
SLUDGE TO DISPOSAL
AIR
AIR BLOWER
SLUDGE RECYCLE PUMP (3)
FEED QUALITY: (MG/L)
TOC 100
NH3 6
PHENOL 20
OIL AND GREASE 8
PH 9-10
FEED FROM CHEMICAL FLOCCULATION
OPERATING PARAMETERS
SLUDGE RETENTION TIME — 30-35 DAYS
SLUDGE VOLUME INDEX — 50-70
FOOD TO MICRO RATIO — 0.1 lb. TOC/DAY / lb. MLVSS

Fig. 2.21 Refinery waste activated sludge process

sulfide tends to mask or interfere with the phenol test. To correct this problem, the hydraulic loading needs to be reduced until DOs are above 1.5 mg/*L* and soda ash should be added to the aeration basin to bring the pH above 6.2 in order to reactivate the phenol eaters. If phenols in the effluent are near your NPDES limit, adding hydrogen peroxide (H_2O_2) can be beneficial.

2.585 Correcting Excessive Phenols

Phenols in excess may pose more of a problem with odor and in extreme cases of phenol shock, microbes will stop working and DOs will increase to the saturation limit. To correct this problem, a decrease in hydraulic loading is necessary and if phenols in the effluent are near the NPDES limit, the addition of H_2O_2 will help to oxidize the phenols.

2.586 Treating Ammonia

Ammonia can be very troublesome since it is related directly to fish toxicity. Ammonia can be difficult to biologically treat because it is difficult to cultivate nitrifying organisms to degrade ammonia. Besides the free ammonia, two other problem compounds that can show up in petroleum refining wastewater are monoethanolamine (MEA) and thiocyanate. Both of these compounds are biologically degraded to ammonia. Lab results must be checked each shift for an indication of a potential increase in ammonia and the maintaining of an MCRT or environment that is conducive to cultivating nitrifying bacteria.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 97.

2.58A What are the three main petroleum refinery waste compounds that can be treated by the activated sludge process?

2.58B Why are MCRTs as high as 30 days necessary to treat petroleum refinery wastes?

2.58C How can a shock load of phenols be treated?

2.59 Summary and Acknowledgments

2.590 Summary

The basic treatment unit in the activated sludge process is a biological reactor (aerated basin or pond). This reactor provides an environment for the conversion of soluble organic material into insoluble microorganism cells. The subsequent unit is a secondary clarifier or pond where the cells are allowed to settle. The settled cells, or sludge, may be either returned to the aeration system, wasted from the system, or stored. As the result of biological growth, large volumes of organic solids are generated in secondary treatment processes.

Although several different activated sludge systems are used to provide secondary treatment (See Sections 11.05 and 11.9) for industrial, domestic, and domestic-industrial wastewaters, the control strategies and/or operating guidelines are essentially the same.

This section has described conditions unique to the treatment of industrial wastewater. Control of your activated sludge system will be enhanced by using the information for the operation and control of your plant contained in various sections of Chapters 8 and 11 of Volumes I and II and this chapter.

2.591 Acknowledgments

Portions of Section 2.50 through 2.54 were taken from "Pollution Abatement in the Fruit and Vegetable Industry" (Volumes 1, 2, and 3), EPA Technology Transfer Seminar Publication, U.S. Environmental Protection Agency, Center for Environmental Research Information, 26 West St. Clair Street, Cincinnati, Ohio 45268.

The representatives of industry who prepared these sections on how to treat industrial wastes are sincerely thanked. Without the contributions from James J. McKeown, Clifford J. Bruell, Peter Luthi, Ralph L. Robbins, Jr., and Cal Davis, this section would not have appeared in this manual.

2.6 EFFLUENT NITRIFICATION

2.60 Need for Effluent Nitrification

Many activated sludge processes are designed to attain a high degree of nitrification. The degree of nitrification that must be attained is dictated by the maximum allowable limit of ammonia nitrogen discharged with the final effluent. This limit is usually governed by the NPDES permit issued by state or federal regulatory agencies.

Nitrogenous compounds discharged from wastewater treatment plants can have several harmful effects. These impacts include ammonia toxicity to fish life, reduction of chlorine disinfection efficiency, an increase in the dissolved oxygen depletion in receiving waters, adverse public health effects (mainly groundwater), and a reduction in the suitability for reuse.

Nitrogen concentrations in raw municipal wastewaters generally range from 15 to 50 mg/*L*, of which approximately 60 percent is ammonia-nitrogen, 40 percent is organic nitrogen, and a negligible amount (one percent) is nitrite and nitrate-nitrogen.

2.61 Nitrogen Removal Methods

Ammonia nitrogen can be reduced in concentration or removed from wastewater by several processes. These processes can be divided into two broad categories: physical-chemical methods and biological methods.

This section is devoted mainly to biological nitrification. A brief discussion of some physical-chemical nitrogen removal methods also is included.

2.610 Ammonia-stripping

The ammonia nitrogen which is present in wastewater during conventional biological treatment can be removed by a physical process called desorption (stripping). Simply stated, the wastewater is first made very alkaline by adding lime, and the ammonia is then induced to leave the water phase and enter the gas phase where it is released to the atmosphere. To accomplish this stripping, the wastewater is contacted with a sufficient quantity of ammonia-free air. This contacting with air is done in a slat-filled tower very similar to those used by industry to cool water.

2.611 Ion Exchange

This nitrogen removal process involves passing ammonia-laden wastewater through a series of columns packed with a material called clinoptilolite. The ammonium ion adheres to or is absorbed by the clinoptilolite. When the first column in a series loses its ammonia adsorptive capacity, it is removed from the treatment scheme and washed with limewater. This step converts the captured ammonium ions to ammonia gas, which is then released to the atmosphere by contacting heated air with the wastewater stream, in much the same manner as described under ammonia stripping.

2.612 Breakpoint Chlorination

Breakpoint chlorination (superchlorination) for nitrogen removal is accomplished by adding chlorine to the wastewater in an amount sufficient to oxidize ammonia-nitrogen to nitrogen gas. After sufficient chlorine has been added to oxidize the organic matter and other readily oxidizable substances present, a stepwise reaction of chlorine with ammonium takes place. This may be the simplest nitrogen removal process, yet it has some disadvantages. In practice, approximately 10 mg/*L* of chlorine is required for every 1 mg/*L* of ammonia-nitrogen. In addition, acidity produced by the reaction must be neutralized by the addition of caustic soda or lime which add greatly to the total dissolved solids in the wastewater.

2.62 Biological Nitrification

The nitrogen present in wastewater predominates as ammonia and organic nitrogen. As the organic matter in the wastewater decomposes, a portion of the organic nitrogen is converted to ammonia nitrogen. When the wastewater is sufficiently aerated, the nitrite forming bacteria (nitrosomonas) will oxidize the ammonia-nitrogen to nitrite-nitrogen. The nitrate forming bacteria (nitrobacter) then oxidize the nitrite-nitrogen to nitrate-nitrogen. Nitrate represents the final form of nitrogen resulting from the oxidation of nitrogenous compounds in the wastewater. The wastewater nitrogen cycle is shown in Figure 2.22.

2.63 Factors Affecting Biological Nitrification

Because of current ammonia removal requirements and anticipation of future "complete nitrogen removal" requirements, you may be required to operate such an activated sludge plant. If you are operating a plant of this type, there are seven principal control guidelines that you must consider to maintain the nitrification process at optimum performance levels:

1. Dissolved oxygen,
2. pH,
3. Wastewater temperature,
4. Nitrogenous food,
5. Detention time,
6. MCRT, F/M, or sludge age, and
7. Toxic materials.

Each of these guidelines must be properly controlled for the successful operation of a biological nitrification process.

1. Dissolved Oxygen (DO)

Nitrification exerts a substantial oxygen requirement. Each pound of ammonium-nitrogen that is nitrified requires approximately 4.6 pounds of oxygen (4.6 kg O_2/kg NH_4^+–N).

Nitrification appears to be uninhibited at DO concentrations of 1 mg/*L* or more. To insure adequate nitrification, the DO in the aeration tank must usually be maintained between 1.0 to 4.0 mg/*L* under average loading conditions. This will include a reasonable DO safety factor. Under peak loading, the DO may fall off somewhat, yet should never fall below 1.0 mg/*L*.

The oxygen requirement may be calculated as shown in the following example.

EXAMPLE

Determine the oxygen requirements for the effluent from a 10 MGD activated sludge plant with an average five-day BOD of 30 mg/*L* and an average ammonium-nitrogen concentration of 15 mg/*L*.

Known		**Unknown**
Flow, MGD	= 10 MGD	Oxygen Requirement, lbs/day
BOD, mg/*L*	= 30 mg/*L*	
NH_4^+–N, mg/*L*	= 15 mg/*L*	

1. Calculate the ammonium-nitrogen load in pounds per day.

$$\begin{aligned}\text{NH}_4^+\text{–N Load, lbs/day} &= \text{Flow, MGD} \times \text{NH}_4^+\text{–N, mg/}L \times 8.34 \text{ lbs/gal}\\ &= 10 \text{ MGD} \times 15 \text{ mg/}L \times 8.34 \text{ lbs/gal}\\ &= 1{,}251 \text{ lbs NH}_4^+\text{–N/day}\end{aligned}$$

2. Calculate the BOD load in pounds per day.

$$\begin{aligned}\text{BOD, lbs/day} &= \text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34 \text{ lbs/gal}\\ &= 10 \text{ MGD} \times 30 \text{ mg/}L \times 8.34 \text{ lbs/gal}\\ &= 2{,}502 \text{ lbs BOD/day}\end{aligned}$$

3. Calculate the ammonium-nitrogen oxygen requirement (pounds per day of oxygen to oxidize ammonia (NH_3) to nitrate (NO_3^-).

$$\begin{aligned}\text{Oxygen, lbs/day } (\text{NH}_4^+\text{–N}) &= \text{NH}_4^+\text{–N}, \frac{\text{lbs}}{\text{day}} \times \frac{4.6 \text{ lbs Oxygen}}{\text{lb NH}_4^+\text{–N}}\\ &= 1251 \frac{\text{lbs NH}_4^+\text{–N}}{\text{day}} \times \frac{4.6 \text{ lbs Oxygen}}{\text{lb NH}_4^+\text{–N}}\\ &= 5{,}755 \text{ lbs Oxygen/day}\end{aligned}$$

4. Calculate the BOD oxygen requirement.

$$\begin{aligned}\text{Oxygen, lbs/day (BOD)} &= \text{BOD}, \frac{\text{lbs}}{\text{day}} \times \frac{1.5 \text{ lbs Oxygen}}{\text{lb BOD}}\\ &= 2502 \frac{\text{lbs BOD}}{\text{day}} \times \frac{1.5 \text{ lbs Oxygen}}{\text{lb BOD}}\\ &= 3{,}753 \text{ lbs Oxygen/day}\end{aligned}$$

5. Calculate the total oxygen requirement to properly oxidize ammonium nitrogen (NH_4^+ –N) and biochemical oxygen demand (BOD).

$$\begin{aligned}\text{Total Oxygen Requirement, lbs/day} &= \text{Oxygen, lbs/day } (\text{NH}_4^+\text{–N}) + \text{Oxygen, lbs/day (BOD)}\\ &= 5{,}755 \text{ lbs/day} + 3{,}753 \text{ lbs/day}\\ &= 9{,}508 \text{ lbs/day}\end{aligned}$$

Because the rate of nitrification will vary significantly with temperature and pH, compensation must be made for these variations. During the summer months, the following methods can be used to match the oxygen requirement to your plant's oxygen capability. These methods attempt to provide more oxygen for nitrification while trying to reduce other oxygen demands.

a. Reduce the aeration system MLSS concentration.

b. Reduce the wastewater pH by reducing chemical addition (if used).

c. Reduce the number of tanks in service while increasing oxygen supply to the tanks remaining in service.

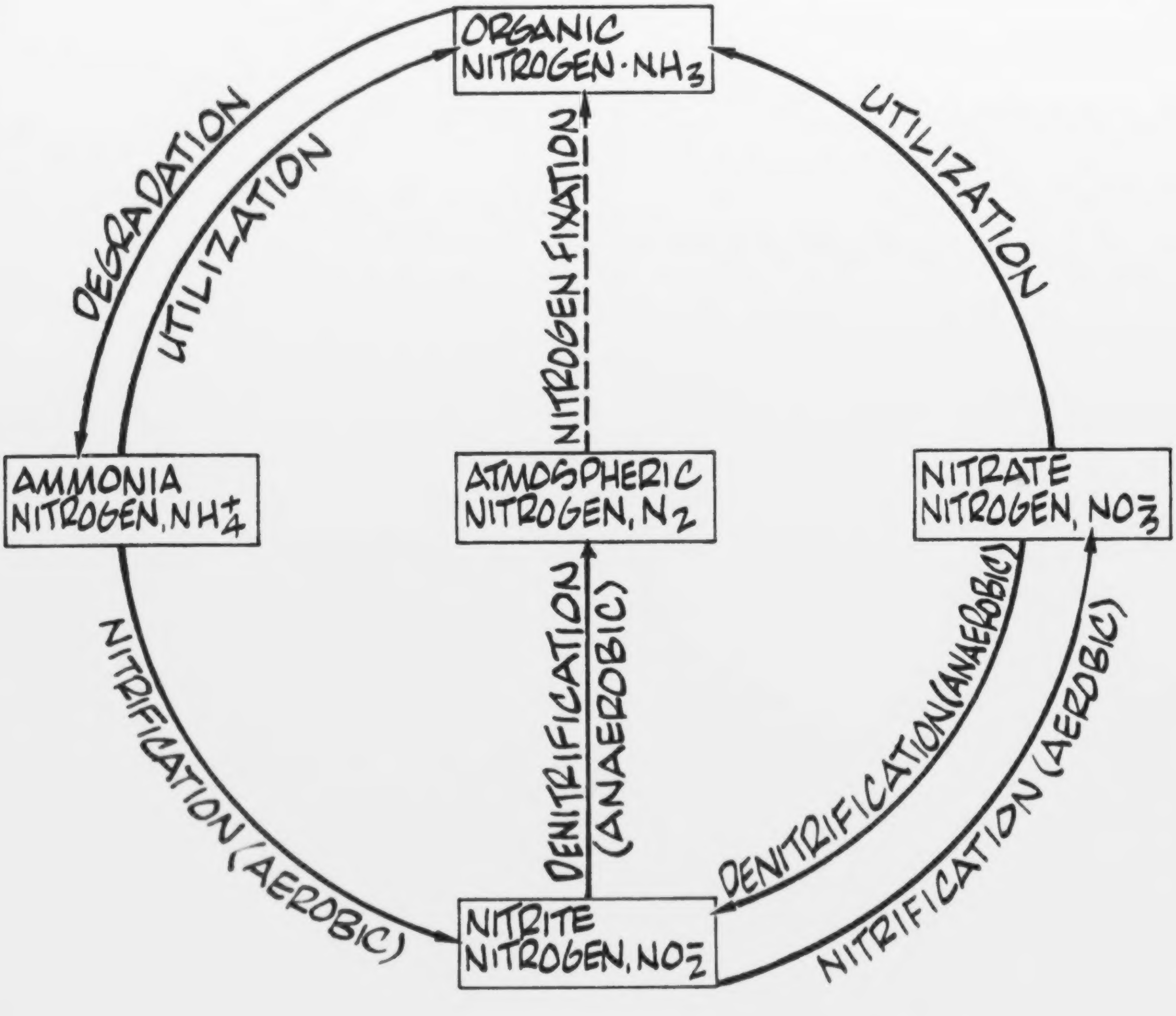

ORGANIC NITROGEN · NH3
AMMONIA NITROGEN, NH4+
ATMOSPHERIC NITROGEN, N2
NITRATE NITROGEN, NO3-
NITRITE NITROGEN, NO2-
DEGRADATION
UTILIZATION
UTILIZATION
NITROGEN FIXATION
DENITRIFICATION (ANAEROBIC)
DENITRIFICATION (ANAEROBIC)
NITRIFICATION (AEROBIC)
NITRIFICATION (AEROBIC)

Fig. 2.22 Wastewater nitrogen cycle

2. pH

In many wastewaters, there is insufficient alkalinity initially present to leave a sufficient residual for buffering the wastewater during the nitrification process. The significance of pH depression in the process is that nitrification rates are rapidly depressed as the pH is reduced below 7.0. Because of the effect of pH on nitrification rate, it is especially important that there be sufficient alkalinity in the wastewater to balance the acid produced by nitrification. A pH of between 7.5 and 8.5 is considered optimal. Approximately 7.2 pounds of alkalinity are destroyed per pound (7.2 kg/kg) of ammonia-nitrogen (NH_3-N) oxidized. Caustic or lime addition may be required to supplement moderately alkaline wastewaters.

If it becomes necessary to add chemicals (preferably lime) for pH adjustment, the required quantities of chemical will vary with wastewater temperature, MLVSS concentration, influent ammonia-nitrogen concentration and the natural alkalinity of the wastewater. As the oxidation of ammonia-nitrogen to nitrate-nitrogen destroys approximately 7.2 pounds of alkalinity per pound (7.2 kg/kg) of ammonia-nitrogen, this loss of alkalinity must be added to the chemical quantity calculated for pH adjustment. For operation under the most adverse temperature and pH conditions, sufficient lime must be added initially to raise the pH into the desired range, and then 5.4 pounds of hydrated lime per pound (5.4 kg/kg) of ammonia-nitrogen will be required to maintain the pH. Sufficient alkalinity should be provided to leave a residual of 30 to 50 mg/*L* after complete nitrification.

3. Temperature

The optimum wastewater temperature range is between 60 to 95 degrees F (15 to 35°C) for good nitrification operation. Nitrification is inhibited at low wastewater temperatures and up to five times as much detention time may be needed to accomplish "complete nitrification" in the winter as is needed in the summer. The growth rate of nitrifying bacteria increases as the wastewater temperature increases and conversely it decreases as the wastewater temperature decreases. Since there is no control over the wastewater temperature, operating compensations for slower winter growth rates are necessary. Increasing the MLVSS concentration, the MCRT, and adjusting the pH to favorable levels can be expected to provide substantial, if not "complete," oxidation of ammonia-nitrogen compounds. Under summer conditions, operation will be possible at less favorable pH levels and lower MLVSS concentrations.

4. Nitrogenous Food

The growth rate of nitrifying bacteria (nitrosomonas and nitrobacter) is affected very little by the organic load applied to the aeration system. However, the population of the nitrifying bacteria will be limited by the amount of nitrogenous food available in the wastewater. Organic nitrogen and phosphorus-containing compounds as well as many trace elements are essential to the growth of microorganisms in the aeration system. The generally recommended ratio of five-day BOD to nitrogen to phosphorus for domestic waste is 100:5:1. Laboratory nitrogen determination (TKN) and phosphorus determination analysis should be performed so that you may add the supplemental phosphorus nutrient if necessary. Phosphorus in the form of phosphate fertilizer may be added and adjusted according to the five-day BOD level and the TKN concentration in the wastewater.

5. Detention Time

The time required for nitrification is directly proportional to the amount of nitrifiers present in the system. Because the rate of oxidation of ammonia-nitrogen is essentially linear or constant, short-circuiting must be prevented. The aeration tank configuration should insure that flow through the tank follows the plug-flow mixing model as closely as possible and provides a minimum detention time of approximately 4.0 hours. Single-pass tanks may be modified and divided into a series of three compartments with ports between them to preclude short-circuiting. Not all of the various modifications to the activated sludge process are appropriate for nitrification applications, although some see use only where partial ammonia removal is required.

6. MCRT, F/M, or Sludge Age

To achieve the desired degree of nitrification, the MCRT must be long enough (usually 4 days plus) to allow the nitrifying bacteria sufficient time to grow. Since the nitrifying bacteria grow much more slowly than the bacteria using the carbonaceous compounds, it is possible to waste the nitrifying bacteria from the system at a higher rate than their growth rate. In simpler terms, this means that nitrification in plants can be maintained only when the rate of growth of nitrifying bacteria is rapid enough to replace organisms lost through sludge wasting. When these bacteria can no longer keep pace, the ability to nitrify decreases and may stop.

When reviewing the performance of your activated sludge process for the selection of an optimum F/M ratio, MCRT or sludge age, oxygen requirements for bacteria using the carbonaceous compounds should be considered along with nitrification requirements. These guidelines should be selected to provide the degree of nitrification required by the discharge permit. If the ammonia-nitrogen limit is being exceeded, the MCRT or sludge age should be increased. Increasing these guidelines will increase the MLVSS and consequently decrease the F/M ratio. With the other conditions (discussed above) constant, a definite relationship will exist between the weight ratio of the ammonia-nitrogen oxidized per day to the MLVSS under aeration.

The growth of cell mass from the oxidation of ammonia is about 0.05 lbs per lb (0.05 kg/kg) of ammonia-nitrogen oxidized. As a result, the degree of nitrification will have little effect on the net sludge yield and WAS rates.

7. Toxic Materials

Various types of toxic materials which will inhibit the nitrification process (in concentrations greater than those indicated) are shown below.

a. Halogen-substituted phenolic compounds, 0.0 mg/*L*.

b. Thiorea and thiorea derivatives, 0.0 mg/*L*.

c. Halogenated solvents, 0.0 mg/*L*.

d. Heavy metals, 10 to 20 mg/*L*.

e. Cyanides and all compounds from which hydrocyanic acid is liberated on acidification, 1 to 2 mg/*L*.

f. Phenol and cresol, 20 mg/*L*.

Pretreatment alternatives provide a degree of removal of the toxicants present in raw wastewater. However, the types of toxicants removed by each pretreatment stage vary among the alternatives. Chemical primary treatment can be used where toxicity from heavy metals is the major problem. Lime primary treatment is one of the most effective processes for removal of a wide range of metals. Chemical treatment is usually not effective for removal of organic toxicants, unless it is coupled with a carbon adsorption step such as in a physical-chemical treatment sequence.

When materials toxic to nitrifiers are present in the raw wastewater on a regular basis, the pretreatment technique most suitable for their removal can be used in the plant to safeguard the nitrifying population. The determination of the most suitable pretreatment process application may be initially developed based on *BENCH SCALE ANALYSIS*[16] to screen alternatives.

The particular pretreatment technique that is effective may also indicate the type of toxicant that is interferring with nitrification and may permit identification and elimination of the source. Subsequent specific analysis can then be run in the identified category of compounds. If the toxicants cannot be eliminated by a source control program, often a pilot study of the process identified by the bench scale tests can be justified to confirm the process selection.

2.64 Rising Sludge and the Nitrification Process

Rising sludge caused by unwanted denitrification in the clarifiers may occasionally plague your nitrification operation. Denitrification occurs because the facultative heterotrophic organisms in the biological sludge in the clarifier accomplish nitrate reduction by what is known as a process of nitrate dissimilation. In this process, nitrate and nitrite replace oxygen in the respiratory process of the organisms under oxygen-deficient conditions. This nitrate dissimilation allows bubbles of nitrogen gas and carbon dioxide to adhere to the sludge floc surface resulting in rising sludge.

The degree of stabilization of the sludge in the aeration tank (depending on detention time and DO) also has a profound effect on denitrification in the clarifier. Clarifier sludges containing partially oxidized or unoxidized organics float more readily than well oxidized sludges. Wastewater temperature is also important as it affects the rate of denitrification and therefore affects the rate of gas and bubble formation (depends on warm temperatures and denitrification rates).

Some considerations for good clarifier operation to preclude denitrification in the clarifier are discussed in the following sections.

1. The settled sludge must be quickly removed from the clarifier to minimize the occurrence and duration of oxygen-deficient conditions. The RAS rate may be proportioned with the aerator influent flow to maintain an essentially "zero" sludge blanket in the clarifier.
2. Since the nitrification sludge is lighter and does not compact as well as carbonaceous sludges, sludges with low SVI values are preferable. They can be withdrawn from the clarifier faster. Since the saturation level of nitrogen is greater in deep tanks than laboratory cylinders, bubbles will form and sludges will float faster in the laboratory than in the field.
3. There is a minimum concentration of nitrate-nitrogen below which there is insufficient nitrogen to cause rising sludge. In weak wastewaters or for those plants in which nitrification is suppressed, rising sludge will not occur.
4. A drop in wastewater temperature will reduce denitrification rates and may render rising sludge a problem only under warmer wastewater conditions.

2.65 Acknowledgments

Major portions of Section 2.6 were taken from *PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES*, Municipal Operations Branch, Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C. 20460, *NITRIFICATION AND DENITRIFICATION FACILITIES, WASTEWATER TREATMENT*, EPA Technology Transfer Publication, U.S. Environmental Protection Agency, center for Environmental Research Information, 26 West St. Clair Street, Cincinnati, Ohio 45268, and *PROCESS DESIGN MANUAL, NITROGEN CONTROL*, U.S. Environmental Protection Agency, Center for Environmental Research Information, 26 West St. Clair Street, Cincinnati, Ohio 45268.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 97.

2.6A List the harmful effects that could result from the discharge of nitrogenous compounds from wastewater treatment plants.

2.6B What are the principal control guidelines for biological nitrification?

2.6C How can you control rising sludge that results from unwanted denitrification?

2.7 REVIEW OF PLANS AND SPECIFICATIONS — PURE OXYGEN ACTIVATED SLUDGE SYSTEMS

2.70 Need to be Familiar with System

The operational staff that reviews the plans and specifications for a pure oxygen plant should be very familiar with the activated sludge process. A tour through an existing pure oxygen system would be extremely helpful. Specific questions regarding the operation and maintenance of the facility can be answered by manufacturers or other treatment plant personnel whose systems use pure oxygen. Also, sources of industrial waste discharges should be identified and investigated for possible toxic wastes, heavy load contributions, and seasonal fluctuations. Be sure your plant has the capacity and flexibility to treat all industrial wastes.

After plans are submitted, the operation and maintenance staff should review all areas of the plans and specifications with special attention directed towards:

1. Physical plant layout,
2. Oxygen generation equipment,
3. Reactor basins (aeration tanks),
4. Oxygen safety and process instrumentation, and
5. Preventive maintenance program.

2.71 Physical Layout

The pure oxygen generation system should be located near the plant maintenance facilities. If this is not possible, an area within the system should be included. This will be an aid during major maintenance on the facility. Major pieces of equipment should be easily accessible. A crane or other lifting devices should be provided to lift large pieces of equipment during major overhauls. Road access and loading facilities should also be provided. Sources of noise and vibrations should also be considered. Most equipment in oxygen production systems produce noise similar to air blower systems and, if not properly installed, could produce vibrations which could be transferred through walls or structures adjacent to such facilities. In offices or laboratories, noise considerations should also be reviewed, especially in plants where housing areas are near the oxygen generation site. Silencers are typically provided with the generation equipment. The overall layout of the system should also allow for expansion of the wastewater treatment plant and oxygen production facilities.

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[16] ***Bench scale analysis.*** *A method of studying different ways of treating wastewater and solids on a small scale in a laboratory.*

2.72 Oxygen Generation Equipment

If the oxygen generation equipment is located within a building, it should be well ventilated. In areas of extremely hot temperatures, vent fans on the roof would be of benefit. A heating system is normally not required if the lowest temperature does not remain below freezing for long periods of time. The compressor equipment generates sufficient heat which can heat the building. Systems located in the open must be designed to operate during the most severe weather conditions.

Individual equipment suppliers recommended by the design engineer should be contacted for specific answers to the installation of compressors, valve skids or oxygen storage facilities. Start-up controls, instrumentation, and safety devices should be carefully reviewed. A vibration shutdown system on compressors should be included. Prior to actual start-up, the manufacturer should run each compressor and check the equipment for proper operation, including excessive vibration. When everything operates in an acceptable manner, calibrate and set vibration monitor to shut down the equipment if excessive vibration develops. This monitor insures proper operation and protection of the equipment. If a separate water cooling system is provided, the water used should be treated to avoid scaling and corrosion of the units.

A specific cleaning requirement should be specified in the plans and specs which would include oxygen pipe lines, sample lines, valve skids and other equipment to insure equipment protection during start-up. Contamination from dirt, grease, and welding slag should never be allowed in a pure oxygen atmosphere. The specifications should include a requirement that equipment manufacturers be present during the start-up and provide a training program to the operations staff. A recommended spare parts list and source of suppliers or vendors should be provided.

Major oxygen feed lines, valves, sample tubing and electrical systems must be tagged and indicated in the "as built" drawings and instruction booklets. Specialized drawings and instruction booklets must include detailed descriptions on preventive maintenance, safety and operation instructions. At least four (4) copies should be provided. Any modification during start-up should be indicated in these manuals.

2.73 Reactors (Aeration Tanks)

The location of the reactor should be reviewed with consideration for future expansion. Reactors located above normal ground elevation should have facilities provided to remove equipment located on the deck. Oxygen reactors are usually completely covered and access to each basin must be provided through a sealed and air-tight lid or locking manhole. Gas sampling lines or other conduits can be installed within the deck. If they are located on the deck, they should be protected and indicated by safety signs to avoid a tripping hazard.

The deck should be a rough surface such as broomed concrete. A completely smooth deck is a slipping hazard if water is allowed to collect. Warning signs should be provided at each entrance to indicate the presence of oxygen and that no smoking or open flames are allowed. A well lighted deck is helpful for night shift operators.

Interior metal such as weir plates, mixer blades and valves should be constructed of stainless steel, carbon steel, or coated carbon steel as dictated by the specific service. A good protective coating should also be provided over any surfaces that may corrode. Control valves should have position indicators and be located in such a manner that preventive maintenance may be performed without draining the reactor. Equipment on the reactor should be tagged with equipment numbers corresponding to electrical control panel facilities.

2.74 Safety and Instrumentation

Operator safety and process safety are both very important in pure oxygen systems. Safety signs, belt guards, temperature shutdown switches and overload protection devices should be provided and indicated in the specifications by the engineer. A system "emergency trip switch" station should be provided and located away from major electrical controls. If tripped during a major mechanical or electrical equipment failure, the entire oxygen operation shuts down without endangering personnel or equipment.

The specifications should include a requirement that the equipment supplier provide a training class to instruct personnel on operation, maintenance, and safety hazards involved in the pure oxygen generation and waste treatment process. Process control involves major instrumentation and control systems. Preventive maintenance on such systems is extremely technical in nature and should be completely understood before maintenance personnel attempt to maintain such systems. The design engineer can provide the necessary background to ensure proper training.

One major area of concern is instrumentation sample tubing and heat trace lines. These systems are the main control and safety equipment functions of the entire system. To avoid costly errors, the manufacturer or equipment supplier should be consulted. If sample lines for lower explosive limit (L.E.L.) or system pressure sensing control lines are incorrectly installed, the entire operation could fail. If they must be installed under roadways, they should be protected within rigid, sealed conduit to prevent being crushed or kinked.

2.75 Preventive Maintenance

Most specifications would not include specific requirements for preventive maintenance. The system design should give consideration to the staff size and experience needs of the system. The design engineer could direct key personnel towards the needs of the system and requirements. Manufacturers can provide maintenance contracts which provide preventive maintenance as well as major tune-ups. Spare parts can be included but can be purchased separately. The cost of such contracts depends on the needs of the system and the options involved.

End of Lesson 4 of 4 Lessons
on
ACTIVATED SLUDGE

Please work the discussion and review questions next.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 4 of 4 Lessons)

Chapter 2. ACTIVATED SLUDGE

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 3.

15. Why would an operator want to monitor the influent to a wastewater treatment plant?
16. How can undesirable constituents be detected in a plant influent in addition to the use of automatic monitoring units?
17. Why should an operational strategy be developed before a toxic waste is discovered in the influent to a plant?
18. Why do some industries pretreat industrial process wastewaters?
19. Why does the operator of an industrial waste treatment plant have to know the flow and waste characteristics of the wastewater being treated?
20. How do toxic materials enter the waste stream?
21. Why should grit, soil, grease and oil be removed from the waste stream?
22. How can the amount of nutrients to be added each day be determined?
23. How does ammonia stripping remove nitrogen from wastewater?
24. How is the nitrification process influenced by temperature?
25. How would you handle materials toxic to a nitrification process?

Please work the objective test next.

X
PLUS
TIMES
MINUS

SUGGESTED ANSWERS

Chapter 2. ACTIVATED SLUDGE

Volume III. Pure Oxygen Plants and Operational Control Options

Answers to questions on page 29.

2.0A Pure oxygen systems dissolve oxygen with a higher efficiency for use by microorganisms treating the wastes. This allows the use of smaller reactor tanks than air activated sludge tanks. The sludge produced has improved settleability and dewaterability.

2.0B Biological nitrification can remove ammonia from wastewater by converting it to nitrate.

Answers to questions on page 33.

2.1A Pure oxygen reactors are staged to increase the efficiency of the use of oxygen.

2.1B As the pure oxygen flows from one stage to the next stage, the oxygen is diluted by the carbon dioxide produced by the microorganisms and the nitrogen stripped from the wastewater being treated.

Answers to questions on page 36.

2.1C The two methods commonly used to produce pure oxygen are:

1. Pressure Swing Adsorption (PSA) Oxygen Generating System;
   and
2. Cryogenic Air Separation Method.

2.1D Cryogenics means very low temperature.

2.1E Cryogenic plants are usually shut down once a year for approximately five to seven days for maintenance.

Answers to questions on page 38.

2.1F Special measurements used to control pure oxygen systems include:

1. Reactor vent gas;
2. Reactor gas space pressure; and
3. Dissolved oxygen.

2.1G Hydrocarbons can be detected before they reach the reactor by installing an L.E.L. detector in the plant headworks.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 41.

2.2A
1. MLSS, **M**ixed **L**iquor **S**uspended **S**olids.
2. MLVSS, **M**ixed **L**iquor **V**olatile **S**uspended **S**olids.
3. RAS, **R**eturn **A**ctivated **S**ludge.
4. F/M, **F**ood to **M**icroorganism Ratio.

2.2B The two basic approaches that can be used to control the RAS flow rate are:

1. Controlling the RAS flow rate independently from the influent flow; and
2. Controlling the RAS flow rate as a constant percentage of influent flow.

Answers to questions on page 41.

2.2C The sludge blanket depth should be kept to one to three feet (0.3 to 1 m) as measured from the clarifier bottom at the sidewall.

2.2D The sludge blanket depth should be measured at the same time every day during the period of maximum flow and high solids loading rate so the depth will be measured under the same conditions of flow and solids loading.

Answers to questions on page 44.

2.2E Techniques used to determine the rate of RAS flow include:

1. Monitoring the depth of the sludge blanket;
2. Settleability approach; and
3. SVI approach.

2.2F Sludge is allowed to settle 30 minutes in the settleability test.

2.2G

Known		Unknown
Infl. Flow, MGD	= 4 MGD	RAS Flow, MGD
Sl. Set. Vol (SV), ml/*L*	= 250 ml/*L*	

1. Calculate RAS flow as a percent of influent flow.

$$\text{RAS Flow, \%} = \frac{\text{SV, ml}/L \times 100\%}{1{,}000\ \text{ml}/L - \text{SV, ml}/L}$$

$$= \frac{250\ \text{ml}/L \times 100\%}{1{,}000\ \text{ml}/L - 250\ \text{ml}/L}$$

$$= \frac{250\ \text{ml}/L \times 100\%}{750\ \text{ml}/L}$$

$$= 33\%\ \text{of influent flow rate}$$

2. Calculate RAS flow, MGD.

$$\begin{aligned}\text{RAS Flow, MGD} &= \text{RAS Flow, decimal} \times \text{Infl. Flow, MGD}\\ &= 0.33 \times 4\text{ MGD}\\ &= 1.33\text{ MGD}\end{aligned}$$

End of answers to questions in lesson 2

Answers to questions on page 47.

2.3A The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food as measured by the COD or BOD test.

2.3B Wasting of the excess activated sludge is usually achieved by removing a portion of the RAS flow. Sometimes wasting is directly from the MLSS in the aeration tank.

2.3C **Known** **Unknown**

Solids Added, lbs/day = 4,750 lbs/day
Solids Aerated, lbs = 41,100 lbs
RAS Susp. Sol., mg/L = 5,800 mg/L
Desired Sludge Age, days = 8 days

WAS Flow, MGD and GPM

1. Calculate the desired solids under aeration for the desired sludge age of 8 days.

$$\begin{aligned}\text{Desired Solids, lbs} &= \text{Solids Added, lbs/day} \times \text{Sludge Age, days}\\ &= 4{,}750\text{ lbs/day} \times 8\text{ days}\\ &= 38{,}000\text{ lbs}\end{aligned}$$

2. Calculate the WAS flow, MGD and GPM to maintain the desired sludge age.

$$\begin{aligned}\text{WAS Flow, MGD} &= \frac{\text{Solids Aerated, lbs} - \text{Desired Solids, lbs}^*}{\text{RAS Susp. Sol., mg/}L \times 8.34\text{ lbs/gal}}\\ &= \frac{(41{,}100\text{ lbs} - 38{,}000\text{ lbs})\text{/day}}{5{,}800\text{ mg/}L \times 8.34\text{ lbs/gal}}\\ &= 0.064\text{ MGD} \times 694\text{ GPM/MGD}\\ &= 45\text{ GPM}\end{aligned}$$

* Difference represents solids wasted in pounds per day.

Answers to questions on page 50.

2.3D Four facts that should be remembered regarding the F/M method of control.

1. The food concentration is estimated by the COD or BOD tests.
2. The amount of food (COD or BOD) applied is important to calculate the F/M.
3. The quantity of microorganisms can be represented by the quantity of MLVSS.
4. The data obtained to calculate the F/M should be based on the seven-day moving average.

2.3E **Known** **Unknown**

$$\text{F/M, } \frac{\text{lbs COD/day}}{\text{lb MLVSS}} = \frac{0.30\text{ lbs COD/day}}{\text{lb MLVSS}}$$

COD added, lbs/day = 7,000 lbs COD/day
Volatile portion = 0.70

MLSS, lbs

1. Determine the desired pounds of MLVSS.

$$\begin{aligned}\text{Desired MLVSS, lbs} &= \frac{\text{COD applied, lbs/day}}{\text{F/M, lbs COD/day/lb MLVSS}}\\ &= \frac{7{,}000\text{ lbs COD/day}}{0.30\text{ lbs COD/day/lb MLVSS}}\\ &= 23{,}333\text{ lbs MLVSS}\end{aligned}$$

2. Determine the desired lbs MLSS.

$$\begin{aligned}\text{Desired MLSS, lbs} &= \frac{\text{Desired MLVSS, lbs}}{\text{MLSS VM portion}}\\ &= \frac{23{,}333\text{ lbs MLVSS}}{0.70}\\ &= 33{,}333\text{ lbs}\end{aligned}$$

2.3F The MCRT expresses the average time a microorganism spends in the activated sludge process.

Answers to questions on page 54.

2.3G The microorganisms that are important indicators in the activated sludge process are the protozoa and rotifers.

2.3H Important activated sludge control tests that are used to define sludge quality and process status include final clarifier sludge blanket depth, mixed liquor and return sludge concentrations, and sludge settleability.

END OF ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 58.

2.4A An industrial waste monitoring program is valuable for the operator of an activated sludge plant for the following reasons:

1. To maintain sufficient control of treatment plant operations to prevent NPDES permit violations; and
2. To gather necessary data for the future design and operation of the treatment plant.

2.4B Common wastewater monitoring devices include:

1. Flow measuring;
2. pH monitoring;
3. Oxidation potential monitoring;
4. Suspended solids monitoring;
5. DO monitoring; and
6. Wastewater samplers.

2.4C If a high organic waste load enters your plant:

1. Gradually increase the RAS flow;
2. Increase the air input to the aeration tanks; and
3. Add nutrients if necessary.

Answers to questions on page 59.

2.50A Types of industries whose wastes could be treated by an activated sludge plant include:

1. Fruit and vegetable processing,
2. Meat and fish processing,
3. Paper product manufacturing, and
4. Petroleum refining.

2.51A The character of industrial wastewater is dependent on the particular production process and the way it is operated.

2.52A One approach to solving a hydraulic overloading problem is to reduce water consumption and minimize waste generation through proper management of processing and production operations.

2.52B The pH of an industrial wastewater can be adjusted (1) upwards by the addition of caustic, and (2) downwards by the addition of sulfuric acid.

2.52C Chemical oxidation (COD) measures the presence of (1) *CARBON* and (2) *HYDROGEN*, but not (3) *AMINO NITROGEN* in organic materials.

2.52D The three major nutrients are carbonaceous organic matter (measured by BOD test), nitrogen (N) and phosphorus (P). Other elements that might be critical include iron, calcium, magnesium, potassium, cobalt, and molybdenum.

2.52E The most common causes or kinds of toxicity in industrial wastewaters include excessive amounts of free ammonia, residual chlorine, detergents, paints, solvents, and biocides.

Answers to questions on page 60.

2.53A Samples from industrial wastewaters should be collected during each operating shift and during different stages of the finished-product and raw-product runs.

2.53B Large variations in flow can be reduced or smoothed out by routing the flows through a surge or storage tank.

2.53C Discrete waste solids (such as trimmings, rejects, corn meal and pulp) are effectively separated from the wastewater flow by various types of screens.

2.53D Screens should be located as close as possible to the process/production producing the waste. The longer the solids are in contact with water and the rougher the flow is handled (more turbulent), the more material will pass through the screens and the more the solids will become dissolved.

Answers to questions on page 63.

2.53E Generally the most economical location to treat toxic wastes is at the source. If possible, do not allow toxic wastes to enter the plant wastewater.

2.53F Industrial waste pretreatment facilities are necessary to treat industrial wastes so they can be treated by the activated sludge process. Pretreatment involves pH adjustment, coarse solids removal, flow equalization, nutrient addition and cooling.

2.53G Screens are used to remove coarse solids to reduce unnecessary clogging and wear on downstream pipes, pumps, aerators and clarifier mechanisms. Also this process will help avoid odor problems that could develop from the settling out of solids in the equalization and emergency basins.

2.53H Organic loadings can be smoothed out by the use of an equalizing tank and also by keeping the contents of the tank well mixed.

2.53I Nitrogen is supplied in the form of ammonia (usually as 30 percent aqueous) and phosphorus as phosphoric acid (usually as 75 percent aqueous).

2.53J "Seed activated sludge" may be obtained from either a nearby municipal or industrial wastewater treatment plant.

2.53K Initially industrial wastes must be added gradually to the aeration basin to allow time for the activated sludge microorganisms to adapt or become acclimated to the wastes.

Answers to questions on page 64.

2.54A Nutrients should be added to wastewater at a point where the incoming wastewater is highly mixed and preferably in the aeration basin.

2.54B Supplemental nitrogen can be provided by aqueous ammonia or anhydrous ammonia. Supplemental phosphorus can be provided by dissolved triple superphosphate, phosphate fertilizer, or phosphoric acid.

2.54C Factors or conditions that have been found to cause the disappearance of higher forms of microorganisms from the activated sludge process include:

1. DO levels below 3 to 4 mg/*L*,
2. High organic loadings,
3. Toxic substances or nutrient deficiencies, and
4. pH control.

2.54D A gradual decrease in percent solids removal from an activated sludge process over a period of time may be the result of grit and silt accumulation in the aeration basin which was not carried out in the effluent and remained in the basin, thus resulting in reduced aeration volume and detention time.

Answers to questions on page 71.

2.55A Accurate records must be kept for the following reasons:

1. To help troubleshoot problems which arise,
2. To account for the operation of the plant during appropriate times, and
3. To serve as legal documents which will protect the company from unjust claims.

2.55B Effluent from a pulp and paper mill activated sludge process should contain some nutrients. If low levels of nutrients are present, a nutrient deficiency could exist in the process.

2.55C The paper industry might shut down an activated sludge process during holidays, maintenance (preventive and emergency), process upsets, strikes, and scheduled production reductions.

2.55D The periodic feeding (step-feed) technique for process start-up of activated sludge systems is effective because it allows organisms time to consume the available food (waste). When they are ready for more food, more is added. This procedure encourages rapid microorganism reproduction.

Answers to questions on page 81.

2.56A Primary clarifiers are not very effective in removing BOD because most of the BOD is "soluble" or "dissolved" and can't be removed by sedimentation.

2.56B Nutrients can be metered into the primary clarifier effluent. To supplement nitrogen, ammonia gas (or liquid) can be added. Phosphoric acid (H_3PO_4) can be used as a source of phosphorus. Sufficient phosphorus may be present in the influent from malting by-products and phosphorus based cleaning solutions.

2.56C The MLSS level in aeration basins is influenced by:

1. Influent organic loading, and
2. Temperature.

2.56D The sludge wasting rate is adjusted in an attempt to regulate the actual MLSS in the aeration basins as close as practical to the desired MLSS "set point."

2.56E Filamentous "bulking" can be controlled by:

1. Proper DO levels in aeration basins,
2. Providing sufficient nutrients (nitrogen and phosphorus) and trace minerals,
3. Proper F/M ratios, and
4. Minimizing large fluctuations or influent organic loadings.

Answers to questions on page 85.

2.57A High strength artichoke waste influents (BOD > 6,000 mg/*L*) are diluted with medium strength wastewater to produce an influent BOD of less than 6,000 mg/*L* before treatment by the activated sludge process.

2.57B Fifteen-day moving averages were computed and plotted for artichoke influent COD and F/M ratio to reduce the effect of fluctuating daily results.

2.57C Ammonium phosphate can be used to provide both nitrogen and phosphorus for the treatment of artichoke wastes.

2.57D If domestic or sanitary wastes are not treated by a dairy waste treatment plant, effluent chlorination may not be necessary.

2.57E High levels of MLSS are necessary to prevent process upsets caused by shock organic loadings.

Answers to questions on page 87.

2.58A The three main petroleum refinery waste compounds that can be treated by the activated sludge process are ammonia, phenols, and sulfide.

2.58B MCRTs as high as 30 days are necessary to treat petroleum refinery wastes in order to maintain the nitrification population necessary to oxidize ammonia.

2.58C A shock load of phenols can be treated by decreasing the hydraulic loading. Hydrogen peroxide can be used to help oxidize phenols in the effluent.

Answers to questions on page 91.

2.6A Harmful effects that could result from the discharge of nitrogenous compounds include:

1. Ammonia toxicity to fish life,
2. Reduction in effectiveness of chlorine disinfection efficiency,
3. Increase in DO depletion of receiving waters,
4. Adverse public health impact on ground water, and
5. Reduction of suitability of water for reuse.

2.6B The principal control guidelines for biological nitrification are:

1. DO,
2. pH,
3. Wastewater temperature,
4. Nitrogenous food,
5. Detention time,
6. MCRT, F/M or sludge age, and
7. Toxic materials.

2.6C Rising sludge resulting from unwanted denitrification can be controlled by:

1. Returning settled sludge as quickly as possible and maintaining essentially "zero" sludge blanket in the clarifier; and
2. Maintain sludges with low SVI values.

END OF ANSWERS TO QUESTIONS IN LESSON 4

OBJECTIVE TEST

Chapter 2. ACTIVATED SLUDGE

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

1. As oxygen rises through the mixed liquor to the surface of a reactor, most of the oxygen is absorbed into the mixed liquor.
   1. True
   2. False
2. Pure oxygen systems may be used to supply oxygen to any of the activated sludge process modes — conventional, step feed, complete mix or contact stabilization.
   1. True
   2. False
3. Operation of the secondary clarifiers, return sludge rates, and wasting rates are much the same for pure oxygen systems as they are for conventional air-activated sludge systems.
   1. True
   2. False
4. Monitoring the depth of the sludge blanket in the clarifier is the most direct method available for determining the RAS flow rate.
   1. True
   2. False
5. A limitation of using the constant flow RAS approach is that the F/M ratio remains constant.
   1. True
   2. False
6. The objective of wasting activated sludge is to maintain a balance between the microorganisms under aeration and the amount of incoming food.
   1. True
   2. False
7. Wasting of activated sludge must be accomplished on a continuous basis.
   1. True
   2. False
8. The character (constituent) of industrial wastewaters depends on the particular production process and the way the process is operated.
   1. True
   2. False
9. All nutrients need to be in a soluble form to be used by the microorganisms in a biological treatment process.
   1. True
   2. False
10. An advantage of biological treatment processes is that the microorganisms can easily adjust to great fluctuations of flows and wastes (BOD).
    1. True
    2. False
11. When should the oxygen vent valve on the last reactor be opened?
    1. When the combined carbon dioxide and nitrogen concentrations reach an excess of 55 percent for an extended period
    2. When the Lower Explosive Limit (L.E.L.) is above 20 percent
    3. When the methane concentration is above 65 percent
    4. When the oxygen concentration drops below 45 percent for an extended period
    5. When the oxygen concentration drops below 75 percent for an extended period.
12. How is oxygen provided to the reactor while a cryogenic unit is shut down for maintenance?
    1. By a standby cryogenic unit
    2. By another parallel cryogenic unit
    3. By surface aerators
    4. By the use of liquid oxygen from storage tanks
    5. By using algae to produce oxygen by photosynthesis
13. Methods use to determine the RAS flow rate include
    1. Mixed liquor volatile suspended solids approach.
    2. Monitoring the depth of the sludge blanket.
    3. Organic loading.
    4. SVI approach.
    5. Settleability approach.
14. How can the sludge blanket depth be measured in the secondary clarifier?
    1. By looking over side of clarifier and reading depth markings on wall
    2. By lowering a surveyor's rod until the end disappears in the blanket
    3. By using a sight glass finder
    4. By using an electronic sludge level detector
    5. By using sonar
15. The amount of waste activated sludge (WAS) removed from the process affects which of the following items?
    1. Effluent quality
    2. Growth rate of microorganisms
    3. Mixed liquor settleability
    4. Occurrence of foaming/frothing
    5. Oxygen consumption

16. When activated sludge is wasted on a continuous basis, the operator should check the return activated sludge volatile suspended solids at least
    1. Every two hours.
    2. Every four hours.
    3. Once every shift.
    4. Every other day.
    5. Once a week.

17. Why do industries pretreat wastewaters before discharging to the collection system?
    1. To impress the public
    2. To keep undesirable constituents out of the sewers
    3. To recover valuable materials
    4. To reduce sewer-service charges
    5. To train operators

18. What types of industrial wastes could inhibit the activity of microorganisms in a treatment plant?
    1. Heavy metals
    2. Low pH wastewaters
    3. Methanol
    4. Organic materials
    5. Toxic wastes

19. How can a toxic waste be discovered in a treatment plant?
    1. Decrease in aerator DO
    2. Decrease in secondary effluent floc
    3. Increase in aerator DO
    4. Increase in plant inflow
    5. Increase in secondary effluent floc

20. The primary disadvantage of the COD test is its susceptability to interference by
    1. Amino nitrogen.
    2. Borate.
    3. Chloride.
    4. Iron.
    5. Sulfide.

21. How can ammonia nitrogen be removed from wastewater?
    1. Ammonia stripping
    2. Biological nitrification
    3. Breakpoint chlorination
    4. Ion exchange
    5. Pressure filtration

22. What is the minimum recommended DO in an aeration tank for biological nitrification?
    1. 0.5 mg/*L*
    2. 1.0 mg/*L*
    3. 1.5 mg/*L*
    4. 2.0 mg/*L*
    5. 4.0 mg/*L*

23. How does breakpoint chlorination remove ammonia?
    1. By breaking down ammonia
    2. By oxidizing ammonia-nitrogen to nitrogen gas
    3. By producing alkalinity conditions
    4. By removing the nitrifying bacteria
    5. By using up the oxygen

24. Procedures used for shutdown and subsequent start-up of activated sludge processes treating industrial wastes vary with the
    1. Crew available for shutdown.
    2. Duration of shutdown.
    3. Microorganisms (MLVSS) in aeration basin.
    4. Nature of shutdown.
    5. Weather expected during shutdown.

25. Important objectives that should be accomplished during shut-downs and start-ups include
    1. Conform with legal requirements (NPDES Permit) for plant effluent.
    2. Delay subsequent start-up as long as possible.
    3. Maintain satisfactory process performance.
    4. No personal injuries.
    5. Treat wastes at a minimum cost for satisfactory performance.

26. Possible techniques for controlling filamentous organisms in an industrial activated sludge process include
    1. Dosage of return sludge with oxidants such as hydrogen peroxide or chlorine.
    2. Lower DO levels in aeration basins so filamentous organisms cannot breathe or respire.
    3. Lower F/M level to starve filamentous organisms.
    4. Reduce nutrients essential for filamentous growth.
    5. Stop sludge wasting to allow activated sludge organisms to gain control.

27. Petroleum refinery wastes that can be treated by the activated sludge process include
    1. Ammonia
    2. Chloride
    3. Iron
    4. Phenols
    5. Sulfide

28. What is the return activated sludge (RAS) flow in GPM when the influent flow is 2 MGD, the mixed liquor suspended solids (MLSS) are 2,200 mg/*L*, and the RAS suspended solids are 8,100 mg/*L*?
    1. 0.55 GPM
    2. 0.75 GPM
    3. 1.875 GPM
    4. 375 GPM
    5. 520 GPM

29. What is the return activated sludge (RAS) flow in GPM when the influent flow is 2.5 MGD and the sludge settling volume (SV) in 30 minutes is 290 ml/*L*?
    1. 0.725 GPM
    2. 1.025 GPM
    3. 505 GPM
    4. 710 GPM
    5. 1,945 GPM

30. An aeration tank has a volume of 1.4 million gallons. The MLSS is 2,400 mg/*L* and the volatile portion is 0.75. The mixed liquor volatile suspended solids (MLVSS) under aeration is
    1. 17,194 lbs.
    2. 21,017 lbs.
    3. 23,120 lbs.
    4. 28,022 lbs.
    5. 30,940 lbs.

31. Calculate the total waste activated sludge (WAS) flow rate in GPM for a plant that adds 3,560 lbs of solids per day. There are 22,470 lbs of solids in the aerator, the RAS suspended solids concentration is 7,100 mg/*L*, and the current WAS flow is 0.02 MGD. The desired sludge age is 6 days.
    1. 0 GPM, stop wasting
    2. 13 GPM
    3. 15 GPM
    4. 27 GPM
    5. 29 GPM

32. Calculate the desired MLSS if the desired F/M ratio is 0.20 lbs COD/day/lb MLVSS, and if 5,000 lbs of COD per day are added, the volatile portion of the solids in the aeration tank is 0.70 and the tank volume is 1.8 MG.
    1. 2,000 mg/*L*
    2. 2,100 mg/*L*
    3. 2,200 mg/*L*
    4. 2,300 mg/*L*
    5. 2,400 mg/*L*

33. Calculate the ammonia (NH_3-N) that must be added in pounds per day to treat an industrial wastewater. Influent flows are 2.5 MGD and primary effluent TOC is 487 mg/*L* with a BOD:TOC ratio of 2.1:1. Primary effluent NH_3-N concentration is 5.61 mg/*L*. Two pounds of NH_3-N are required for every 100 pounds of BOD treated. Select the closest answer.
    1. 100 lbs NH_3-N/day
    2. 200 lbs NH_3-N/day
    3. 300 lbs NH_3-N/day
    4. 400 lbs NH_3-N/day
    5. 450 lbs NH_3-N/day

END OF OBJECTIVE TEST

CHAPTER 3

PHYSICAL-CHEMICAL TREATMENT

by

James L. Johnson

and

Ross Gudgel

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OBJECTIVES

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

After completeion of Chapter 3, you should be able to do the following:

CHEMICALS

1. Describe the proper procedures for using chemicals to remove solids from your treatment plant's secondary effluent.
2. Operate and maintain chemical feed equipment.
3. Safely store and handle chemicals.
4. Review plans and specifications of chemical feed systems.
5. Start up and shut down a chemical feed system.
6. Select the most cost-effective chemicals and determine proper dosage.
7. Troubleshoot a chemical feed system.
8. Develop an operational strategy for a chemical feed system.

MICROSCREENS

1. Identify and describe the components of a microscreen unit.
2. Safely operate and maintain a microscreen.
3. Start up and shut down a microscreen unit.
4. Troubleshoot a microscreen treatment process.
5. Develop an operational strategy for a microscreen treatment process.
6. Review plans and specifications for microscreens.

FILTRATION

1. Identify and describe the components of gravity and pressure filters.
2. Safely operate and maintain filters.
3. Start up and shut down filters.
4. Troubleshoot a filtration system.
5. Develop operational strategies for gravity and pressure filtration systems.
6. Review plans and specifications for filter systems.

GLOSSARY

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

AGE TANK AGE TANK

A tank used to store a known concentration of chemical solution for feed to a chemical feeder. Also called a "day tank."

AIR BINDING AIR BINDING

The clogging of a filter, pipe or pump due to the presence of air released from water.

ANHYDROUS (an-HI-drous) ANHYDROUS

Very dry. No water or dampness is present.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reacter is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

COAGULATION (co-AGG-you-LAY-shun) COAGULATION

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

CONTINUOUS PROCESS CONTINUOUS PROCESS

A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.

DAY TANK DAY TANK

A tank used to store a known concentration of chemical solution for feed to a chemical feeder. Also called an "age tank."

ELECTROLYTE (ELECT-tro-LIGHT) ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

FILTER AID FILTER AID

A chemical (usually a polymer) added to water to help remove fine colloidal suspended solids.

FLOCCULATION (FLOCK-you-LAY-shun) FLOCCULATION

The gathering together of fine particles to form larger particles.

FLOW-EQUALIZATION SYSTEM FLOW-EQUALIZATION SYSTEM

A device or tank designed to hold back or store a portion of peak flows for release during low-flow periods.

JAR TEST JAR TEST

A laboratory procedure that simulates coagulation/flocculation with differing chemical doses. The purpose of the procedure is to *ESTIMATE* the minimum coagulant dose required to achieve certain water quality goals. Samples of water to be treated are placed in six jars. Various amounts of chemicals are added to each jar, stirred and the settling of the solids is observed. The lowest dose of chemicals that provides satisfactory settling is the dose used to treat the water.

POLYELECTROLYTE (POLY-electro-light) POLYELECTROLYTE

A high-molecular-weight substance that is formed by either a natural or a synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polymer."

POLYMER (POLY-mer) POLYMER

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polymers may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polymers consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polyelectrolyte."

SLAKE SLAKE

To become mixed with water so that a true chemical reaction takes place, such as in the slaking of lime.

TURBIDITY UNITS (TU) TURBIDITY UNITS (TU)

Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water, they are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.

CHAPTER 3. PHYSICAL-CHEMICAL TREATMENT

(Lesson 1 of 4 Lessons)

3.0 NEED TO REMOVE SOLIDS FROM SECONDARY EFFLUENTS

As increasing demands are placed upon our nation's receiving waters, it has become necessary to set wastewater treatment plant discharge standards at a level that cannot be consistently met by conventional secondary wastewater treatment plants. Physical-chemical treatment processes may be used by industry to treat secondary effluents or specific wastestreams depending on the wastes and discharge requirements.

At some locations, National Pollutant Discharge Elimination System (NPDES) discharge requirements as stringent as those listed in Table 3.1 are being imposed. To comply with these requirements, the effluent from a standard secondary treatment plant or pond system must receive additional or tertiary treatment. Improving solids removal from the effluent of secondary wastewater treatment plants may be accomplished by chemical addition or by several filtration processes. In addition to removing solids, these treatment processes also remove particulates, BOD and coliforms. This chapter will review methods presently in use for upgrading solids removal from the effluent of secondary treatment plants. These tertiary treatment methods include the addition of chemicals, microscreens, and gravity and pressure filters. Figure 3.1 shows the location of these tertiary treatment processes in relation to other conventional processes.

TABLE 3.1 EXAMPLE OF STRICT NPDES REQUIREMENTS

Water Quality Indicator	7-day Average	30-day Average	No Sample to Exceed
Biochemical Oxygen Demand (BOD_5), mg/*L*	5	5	7.5
Suspended Solids, mg/*L*	5	5	7.5
Total Coliform, MPN/100 ml *MEDIAN*, not average	2.2	2.2	240
Chlorine Residual, mg/*L* *AFTER* dechlorination	0	0	0

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 167.

3.0A What do the initials NPDES stand for?

3.0B Why do some locations have stringent discharge requirements?

3.0C How can solids be removed from secondary effluents?

3.1 SOLIDS REMOVAL FROM SECONDARY EFFLUENTS USING CHEMICALS

Chemical treatment is a three-step process consisting of 1) *COAGULATION*[1], 2) *FLOCCULATION*[2], and 3) liquid/solids separation. The three steps must occur in the proper sequence. During the coagulation phase the chemical(s) are added to the wastewater and rapidly mixed with the process flow. At this time certain chemical reactions occur quickly, resulting in the formation of very small particles usually called "pin point floc."

Flocculation follows coagulation and consists of gentle mixing of the wastewater. The purpose of the gentle or slow mixing is to produce larger, denser floc particles that will settle rapidly. The liquid/solids separation step follows flocculation and is almost always conventional gravity settling, although other processes such as dissolved air flotation are used occasionally.

A chemical treatment process can be added on to an existing primary or secondary treatment plant as a tertiary treatment process. Chemical treatment performed in this manner requires the construction of additional basins or tanks, which may significantly increase the capital cost of the treatment plant. However, chemical treatment can be practiced by adding chemicals at specific locations in existing primary or secondary treatment plants. This approach is often called chemical addition, and it eliminates the need for constructing additional clarifiers.

Regardless of the form of the chemical treatment process (tertiary or chemical addition), the most important process control guidelines are:

1. Providing enough energy to completely mix the chemicals with the wastewater,
2. Controlling the intensity of mixing during flocculation, and
3. Controlling the chemical(s) dose.

Chemical treatment can easily be added to existing secondary treatment processes as chemical addition, and it may be added on a permanent basis to remove solids from the secondary effluent (Fig. 3.2). Filters (Sections 3.3 and 3.4) often are installed after chemical treatment to produce a highly polished effluent. Also, chemicals may be added to reduce emergency problems such as those created by sludge bulking in the secondary clarifier, upstream equipment failure, accidental spills entering the plant, and seasonal overloads. Chemicals can effectively be used as a "band-aid" during problem situations with relatively minor capital expense.

---

[1] *Coagulation (co-AGG-you-LAY-shun). The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.*

[2] *Flocculation (FLOCK-you-LAY-shun). The gathering together of fine particles to form larger particles.*

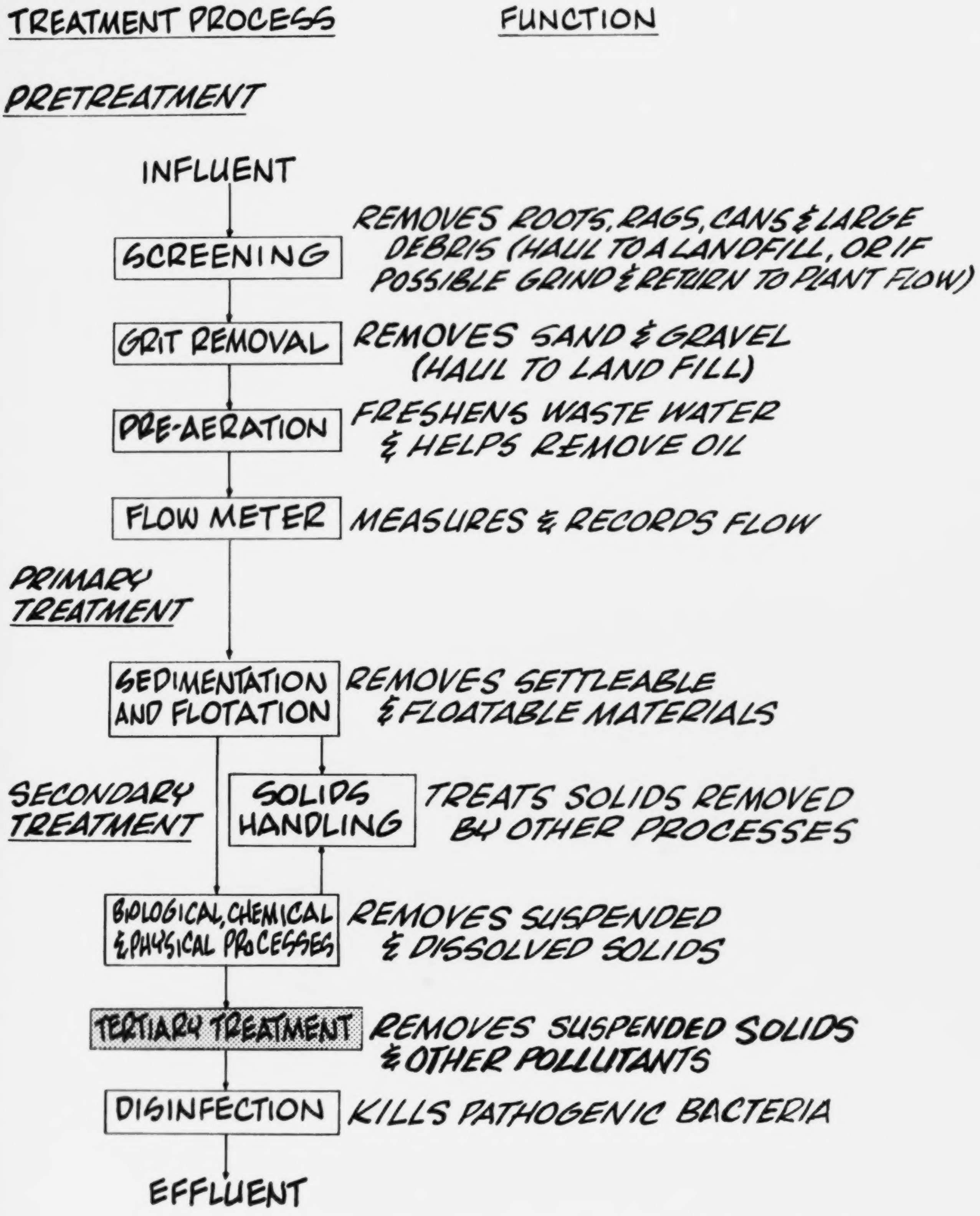

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
BIOLOGICAL, CHEMICAL & PHYSICAL PROCESSES
REMOVES SUSPENDED & DISSOLVED SOLIDS
TERTIARY TREATMENT
REMOVES SUSPENDED SOLIDS & OTHER POLLUTANTS
DISINFECTION
KILLS PATHOGENIC BACTERIA
EFFLUENT

Fig. 3.1 Flow diagram of a typical plant

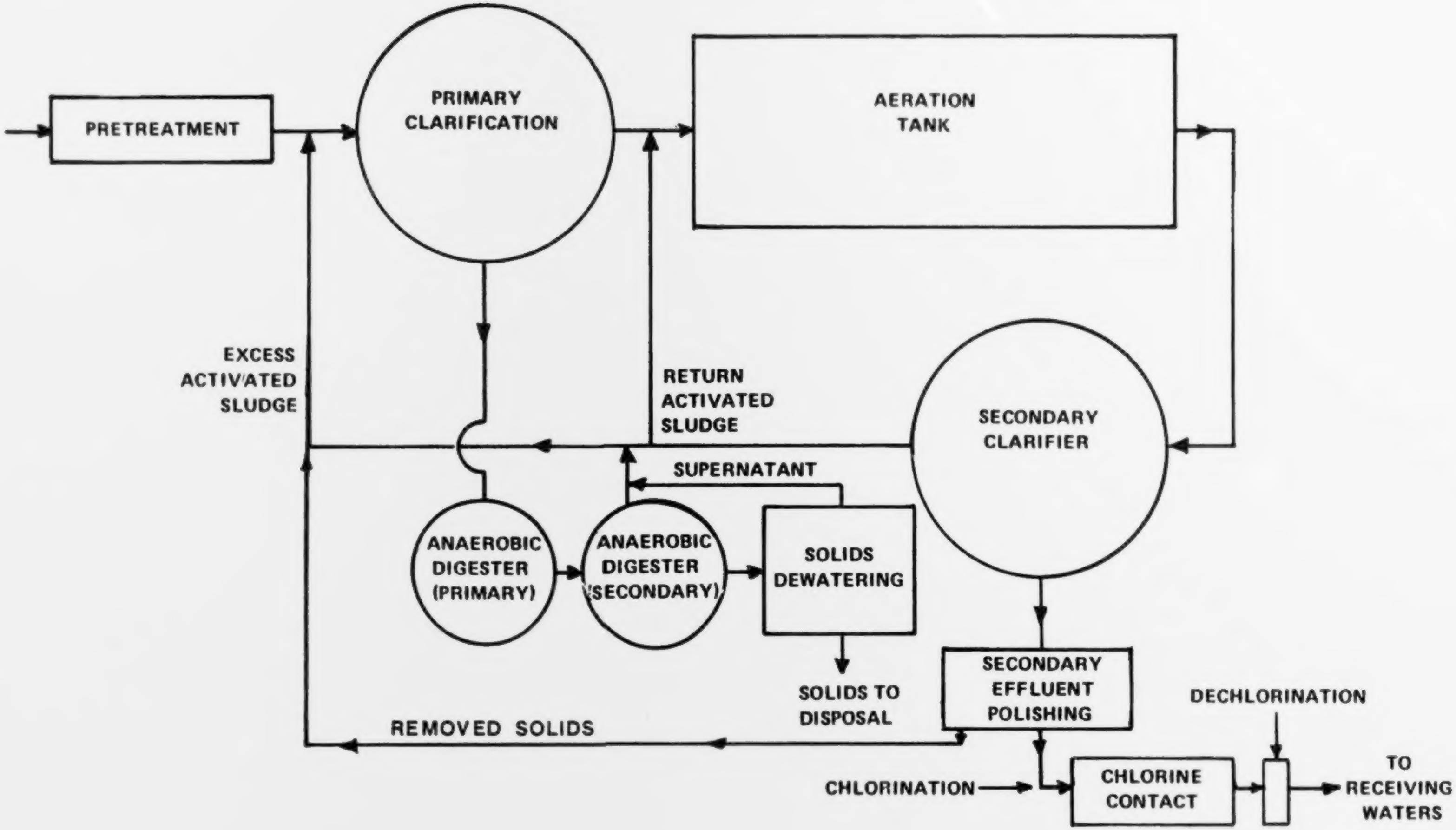

PRETREATMENT
PRIMARY CLARIFICATION
AERATION TANK
EXCESS ACTIVATED SLUDGE
RETURN ACTIVATED SLUDGE
SECONDARY CLARIFIER
SUPERNATANT
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SOLIDS DEWATERING
SOLIDS TO DISPOSAL
SECONDARY EFFLUENT POLISHING
DECHLORINATION
REMOVED SOLIDS
CHLORINATION
CHLORINE CONTACT
TO RECEIVING WATERS

Fig. 3.2 Plan layout of a typical activated sludge plant with secondary effluent polishing process

Keep in mind that the addition of chemicals is usually meant to capture some additional solids; therefore, more sludge must be handled. Care must be taken in controlling dosage into the secondary system because large chemical additions may be toxic to the organisms. This will reduce the activity or even kill the organisms treating the wastes in the system.

Whenever applying chemicals it is important to always know, understand, and carefully control the dosage. You must understand each chemical's characteristics so the chemical will be properly stored and safely handled. *MANY OF THE CHEMICALS USED ARE HARMFUL, ESPECIALLY TO THE EYES. SAFETY IS OF THE UTMOST IMPORTANCE WHEN CHEMICALS ARE STORED OR APPLIED.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 167.

3.1A Why might chemicals be used in a wastewater treatment plant in addition to removing solids from secondary effluents?

3.1B What precaution must be exercised when adding chemicals upstream from a biological treatment process?

3.10 Chemical Added to Improve Settling

Secondary effluent quality may be improved by adding coagulant aids ahead of the secondary settling tanks. Chemicals usually added are alum, ferric chloride, lime or polyelectrolytes. Other useful chemicals may include sodium aluminate, ferric sulfate, ferrous chloride and ferrous sulfate. These chemicals may be used alone or in combinations as determined by laboratory testing (Section 3.12, "Determining Chemical Dosage") and the results obtained in actual plant operation.

3.100 Aluminum Sulfate (Dry) ($Al_2(SO_4)_3 \cdot 14\ H_2O$)

Alum may be purchased in varying grades identified as lump, ground, rice, and powdered. Lump alum consists of lumps varying in size from 0.8 inches to 8 inches (2 to 20 cm) in diameter and is rarely used due to its irregularity in size and the difficulties of applying and achieving a satisfactory dose. Ground (granulated) alum is a mixture of rice-size material and some fines (very small particles). This form of alum is used by the majority of the water and wastewater plants. Ground alum feeds easily and doesn't bulk (stick together) in the hoppers if kept free of moisture or water. Also, ground alum doesn't require special protection of the hopper interiors from corrosion and wear.

Commercial filter alum (ground alum) is shipped in 100-pound (45 kg) bags or in bulk trucks and railroad hopper cars. Special care should be taken to prevent alum from getting damp or it will cake into a solid lump. All mechanical equipment, such as conveyors, should be run until well-cleaned of all alum before shutting down because the alum can harden and jam the equipment. Keep alum dry by storing it inside a well-ventilated location. Storage bins should have a 60-degree slope to the bottom to insure complete emptying. Be sure the alum will not get wet when hosing down equipment or washing floors.

Both dry dust and liquid forms of alum are irritating to the skin and mucous membranes and can cause serious eye injury. Wear protective clothing to protect yourself from dust, splashes, or sprays. Proper clothing consists of a face shield, rubber gloves, rubber shoes and rubber clothing when working around alum dust.

3.101 Aluminum Sulfate (Liquid)

Alum is also available as a liquid. One gallon weighs about 11 pounds and contains the equivalent of 5.4 pounds of dry aluminum sulfate. Obtain a chemical analysis from the supplier for each delivery to determine the exact content. Liquid alum is preferred by operators because of its ease of handling; however, you must pay shipping costs for transporting the water portion.

Liquid alum is shipped in 2,000- to 4,000-gallon tank trucks or 55- to 110-ton railroad tank cars.

Alum becomes very corrosive when mixed with water; therefore, dissolving tanks, pumps and piping must be protected. Liquid storage tanks must be constructed of corrosion resistant material such as rubber-lined steel or fiberglass. Bulk liquid alum storage tanks must be protected from extreme cold because normal commercial concentrations will crystallize at temperatures below 32°F (0°C) and freeze at about 18°F (−8°C).

Alum will support a bacterial growth and/or cause sludge deposits in feed lines if wastewater is used to transport the alum to the point of application. These growths and deposits can completely plug the chemical feed line. This problem can be reduced by maintaining a high velocity to scour the line continuously. Also, a concentrated alum solution will not support the bacterial growth so reducing the amount of carrier water helps.

Alum reduces the alkalinity in the water being treated during the coagulation process. Hydrated lime, soda ash, or caustic soda may be required if there isn't enough natural alkalinity present to satisfy the alum dosage.

Overdosing of alum may depress the pH to a point that it will reduce the biological activity in the secondary system. Also, this lowered pH may allow the chlorine added as a disinfectant to further depress the pH and affect the aquatic life in the receiving waters. This, along with chemical costs, emphasizes the need to maintain proper chemical dosages and close monitoring of effluent quality.

Regularly analyze the bulk chemicals to determine if the concentration has changed. If the concentration has changed, the operator must adjust the chemical feed rate. Also test the effluent quality to determine if sufficient solids are being removed or if an adjustment in the chemical feed rate might be helpful.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 167.

3.1C What are the four most common chemicals added to improve settling of solids?

3.1D Why should alum be kept dry?

3.1E Why should all mechanical equipment, such as conveyors, be run until well-cleaned of all alum before shutting down?

3.102 Ferric Chloride

Ferric chloride is available in three forms — *ANHYDROUS*[3], crystal hydrated and liquid. The dry forms will absorb enough moisture from the air to quickly form highly corrosive solutions.

Anhydrous ferric chloride is shipped in 150- and 350-pound drums. Once these drums are opened, they should be completely emptied to prevent the formation of corrosive solutions. Care must be taken when making up solutions because the temperature of the solution will rise as the chemical dissolves.

Crystal ferric chloride is shipped in 100-, 400-, or 450-pound drums. Store the crystals in a cool, dry place and always completely empty any opened containers. The heat rise in dissolving crystal ferric chloride is much lower than that of anhydrous ferric chloride and is not a problem.

Liquid ferric chloride is shipped in rubber-linked tank cars or trucks and must be stored in corrosion-resistant tanks.

Positive displacement metering pumps should be used for accurate measurements. Both the feeder and the lines must be corrosion-resistant.

All forms of ferric chloride will cause bad stains. This staining will occur on almost every material including walls, floors, equipment and even operators.

Safety precautions required for handling ferric chloride in concentrated forms should be the same as those for acids. Wear protective clothing, face shields and gloves. Flush off all splashes on clothing and skin immediately.

3.103 Lime

Hydrated lime (calcium hydroxide or $Ca(OH)_2$) is used to coagulate solids or adjust the pH to improve the coagulation process of other chemicals. Lime may be purchased in 50- or 100-pound bags or in bulk truck or railroad car loads. Lime should be stored in a dry place to avoid absorbing moisture.

Lime also may be purchased as anhydrous or quicklime, but must be *SLAKED*[4] before using. Quicklime is more difficult to store because it will easily absorb moisture and cake. Quicklime is less expensive to purchase than lime; however, the added equipment for slaking and the requirement for increased operational safety must be considered.

Heat is generated when water is added to quicklime. If the controlled water supply fails and the water is shut off while the lime feed continues, boiling temperatures can be reached quickly. If a boiling reaction results, hot lime may cause the slaker to erupt and spew out hot lime. If high temperature controls are properly installed, they should activate an alarm and/or shut down the unit. Mixers and pumps should be inspected frequently (daily) for wear because the lime slurry will rapidly erode or wear moving parts.

When transporting concentrated lime slurries in pipelines, a scale will build up on the inside of the pipe and eventually plug the line. A 2- to 3-inch (50 to 60 mm) diameter pipe may need replacing every year or two due to this scale. Rubber or flexible piping with easy access and short runs will permit cleaning by squeezing the walls and washing out the broken scale. Standby lines should be provided for use during the cleaning operation.

Lime is irritating to the skin, the eyes, the mucous membranes and the lungs. Protect your eyes and lungs with safety equipment and wear protective clothing when working around lime.

3.104 Polymeric Flocculants

Polymeric flocculants are high-molecular-weight organic compounds with the characteristics of both polymers and *ELECTROLYTES*[5]. They are commonly called *POLYELECTROLYTES*[6]. These flocculants may be of natural or synthetic origin. Polyelectrolytes are classified on the basis of the type of charge on the polymer chain. Negative-charged polymers are called "anionic" and positive-charged polymers are called "cationic." Polymers carrying no electrical charge are called "nonionic polyelectrolytes."

A great assortment of polyelectrolytes is available to the wastewater plant operator. They may be applied alone or in combination with other chemicals to aid coagulation. With this large selection of polymers available, it is possible to find a beneficial combination for almost all conditions. Because of this selection, extensive laboratory testing should be conducted before treating the entire plant effluent. Most polyelectrolyte suppliers have field representatives who will assist with the testing of their products at the treatment plant.

Polyelectrolytes are commonly used in very small doses, usually less than 1 mg/*L*. The effective dosage range is limited. An overdose can be worse than no polymer addition at all.

Polyelectrolytes are available as a dry powder or as a liquid. Care must be taken when storing powders because they may quickly absorb moisture and become ineffective.

Solutions for treating wastewater are made up from powders in a batch tank and fed from a separate tank. When mixing a batch, care is required to add the powder slowly while continuously mixing. If care is not taken, useless lumps will form that can clog feed pumps and lines.

Polyelectrolytes are considered non-hazardous to handle; however, good housekeeping must be practiced because polyelectrolytes will create an extremely slippery surface when wet. Clean up spills immediately! Chlorine will break down a polyelectrolyte. To clean up a spill, neutralize the polyelectrolyte with either salt (NaCl), liquid bleach or HTH powder. This procedure may be used with any type of polyelectrolyte. Some polyelectrolytes have a low pH and can be corrosive to the make-up day or age tank (tank used to store solution).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 167 and 168.

3.1F What safety precautions are required for handling ferric chloride in concentrated solutions?

3.1G How can the scale of lime that builds up on the inside of pipe be cleared?

3.1H What problems can be created when a polyelectrolyte is spilled?

3.1I How would you clean up a polyelectrolyte spill?

---

[3] *Anhydrous (an-HI-drous). Very dry. No water or dampness is present.*

[4] *Slake. To become mixed with water so that a true chemical reaction takes place, such as in the slaking of lime.*

[5] *Electrolyte (ELECT-tro-LIGHT). A substance which dissociates (separates) into two or more ions when it is dissolved in water.*

[6] *Polyelectrolyte (POLY-electro-light). A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polymer."*

3.11 Chemical Mixing Equipment

Chemical mixing equipment (Figure 3.3) is needed to prepare a solution of known concentration that can be metered (measured) into the water being treated. Polyelectrolytes can be difficult to dissolve. Also polyelectrolytes may need a period of aging prior to application. A dissolving tank with a mechanical mixer is used to prepare the solution for feeding. The resulting solution is stored in a day tank (holding tank) from which it is metered out at the proper dosage into the water being treated.

3.12 Chemical Feed Equipment

Chemical feeders (metering equipment) are required to accurately control the desired dosage. The chemical to be used and the form in which it will be purchased must be determined first because chemicals used for solids removal in wastewater treatment usually can be purchased in either solid or liquid form.

After metering, solid chemicals are generally converted into a solution or a slurry prior to applying to the wastewater stream. Both slurries and liquids often have flushing water used to rapidly carry the chemical to the point of application.

3.120 Types of Chemical Metering Equipment

To maintain accurate feed rates there cannot be any slippage in the metering equipment; therefore, most liquid feeders are of the positive displacement type. The quality of the water used for both mixing and flushing the polymer system is important. Poor quality plant effluent may cause clumps ("fish eyes") to form which will plug feeders, small orifices and even piping.

POSITIVE DISPLACEMENT PUMPS

A piston pump (Figure 3.4) is used for metering chemicals due to the accuracy of the positive displacement stroke and the ease of adjusting the piston stroke to regulate the chemical feed rate. With each stroke a fixed amount or volume of chemical or solution is discharged. By knowing the amount discharged per stroke and the number of strokes per minute, it is easy to calculate the chemical output.

Other positive displacement pumps besides the piston pump include the gear pump (Fig. 3.4) and the diaphragm pump (Figs. 3.5 and 3.6). Each of these pumps will produce a constant chemical flow rate for a specific setting.

The feed rate for dry chemicals must also be accurately controlled. Typical dry chemical feeders include the screw feeder, vibrating trough, rotating feeder, and belt-type gravimetric feeder.

SCREW FEEDER

A screw feeder unit maintains a desired output by varying the speed and/or the amount of time the screw rotates as it moves chemicals out the discharge port. Care must be taken that the chemical doesn't cake up in the hopper and stop feeding the screw. Also, the screw must be kept clean or the amount discharged per revolution will change (Fig. 3.7).

VIBRATING TROUGH FEEDER

The vibrating trough maintains a constant depth of chemical discharged and controls its chemical output by the magnitude and the length of time of the vibrations.

Care must be taken that the chemical doesn't cake in the hopper and stop feeding into the trough. Also, caking on the trough will prevent an even flow of chemical which could change the output volume.

ROTARY FEEDER

Rotary feeders are similar to the positive displacement gear pump because a fixed amount of chemical is discharged from between each tooth (Fig. 3.8). The output can be controlled by the speed and/or running time of the rotor. Care must be taken to maintain the rotor lobes clean and free of buildup that will change the chemical output volume.

BELT-TYPE GRAVIMETRIC FEEDER

A gravimetric belt feeder (Fig. 3.9) maintains a constant chemical weight on a revolving belt. This is accomplished using a vibrating trough and a balance system. The chemical output is controlled by the amount of chemical on the belt and the speed and time the belt travels. The amount of chemical is varied by the opening or closing of a feed gate or as a weighing deck moves up or down.

Care must be taken with this unit to assure that chemicals don't buildup on the balance because this will change the chemical output. By catching and weighing the chemical discharged at a constant speed over a measured amount of time, the feeder output can be calculated.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.1J How are chemical solutions prepared for feeding?

3.1K List the most common types of chemical feeders or metering equipment.

3.121 Selecting a Chemical Feeder

When you must decide which chemical feeder to purchase for your situation, include the following considerations:

1. *TOTAL OPERATING RANGE*

   Will the unit run at today's lowest expected chemical output as well as the future required output?

2. *ACCURACY*

   Will the unit maintain the same feed rate after it has been installed, calibrated and operated?

3. *REPEATABILITY*

   Can you return to previous settings and obtain the same feed rates as before?

4. *RESISTANCE TO CORROSION*

   Will the equipment, including electrical components, withstand the corrosive environment to which they may be exposed?

5. *DUST CONTROL*

   Is a means provided to control dust if needed?

6. *AVAILABILITY OF PARTS*

   Are replacement parts readily available?

7. *SAFETY*

   Is the system designed with safety of both operation and maintenance in mind?

8. *ECONOMICS*

   Costs of purchase, installation, operation, maintenance, replacement and energy requirements.

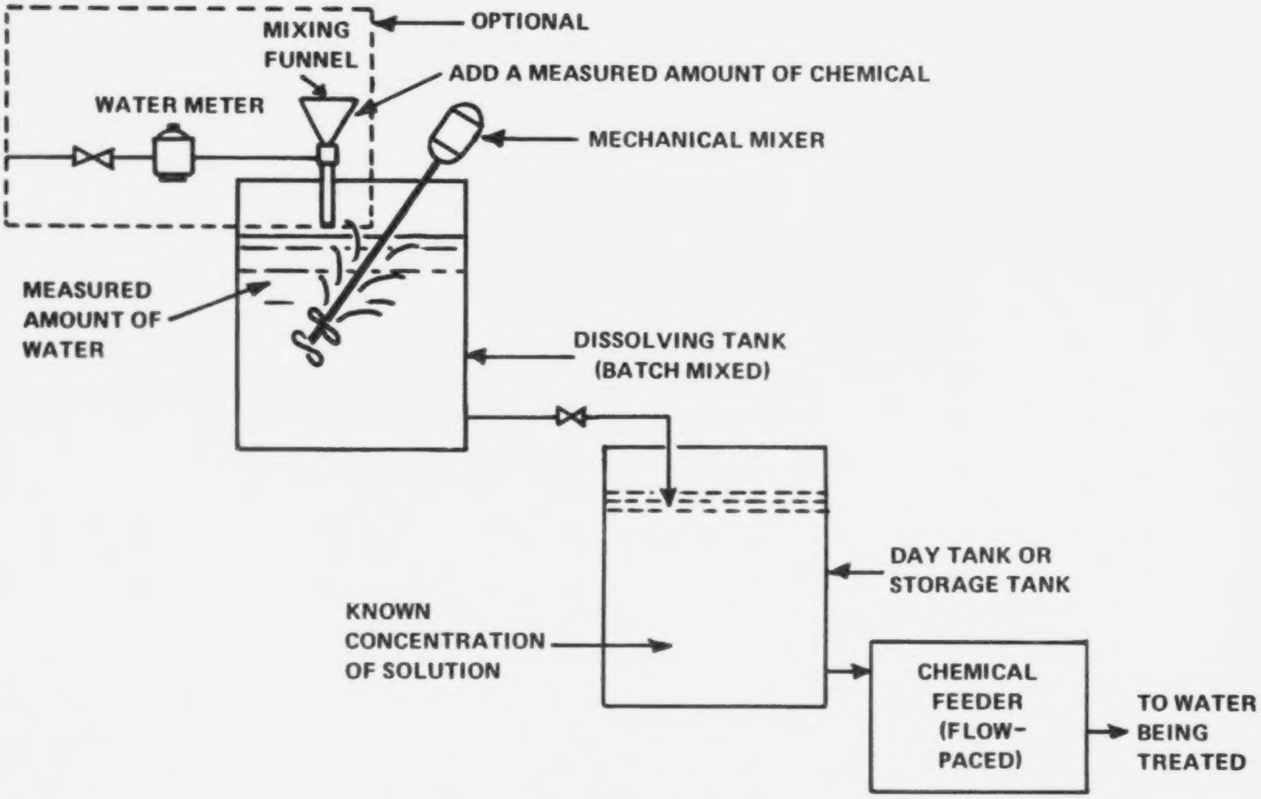
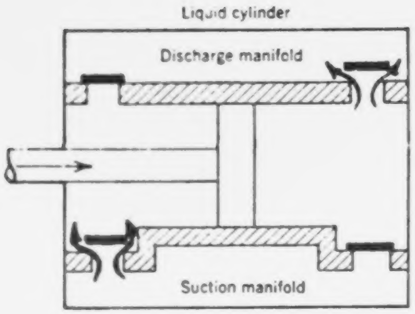
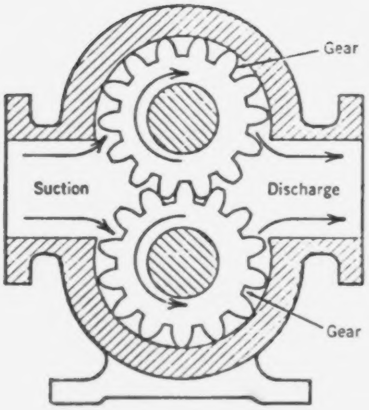

OPTIONAL
MIXING FUNNEL
ADD A MEASURED AMOUNT OF CHEMICAL
WATER METER
MECHANICAL MIXER
MEASURED AMOUNT OF WATER
DISSOLVING TANK (BATCH MIXED)
DAY TANK OR STORAGE TANK
KNOWN CONCENTRATION OF SOLUTION
CHEMICAL FEEDER (FLOW-PACED)
TO WATER BEING TREATED

Fig. 3.3 Dry chemical dissolver, day tank and feeder


Liquid cylinder
Discharge manifold
Suction manifold

PISTON PUMP


Gear
Suction
Discharge
Gear

GEAR PUMP

Fig. 3.4 Piston and gear pump
(Courtesy of Chemical Engineering, 76 8, 45 (April 1969))

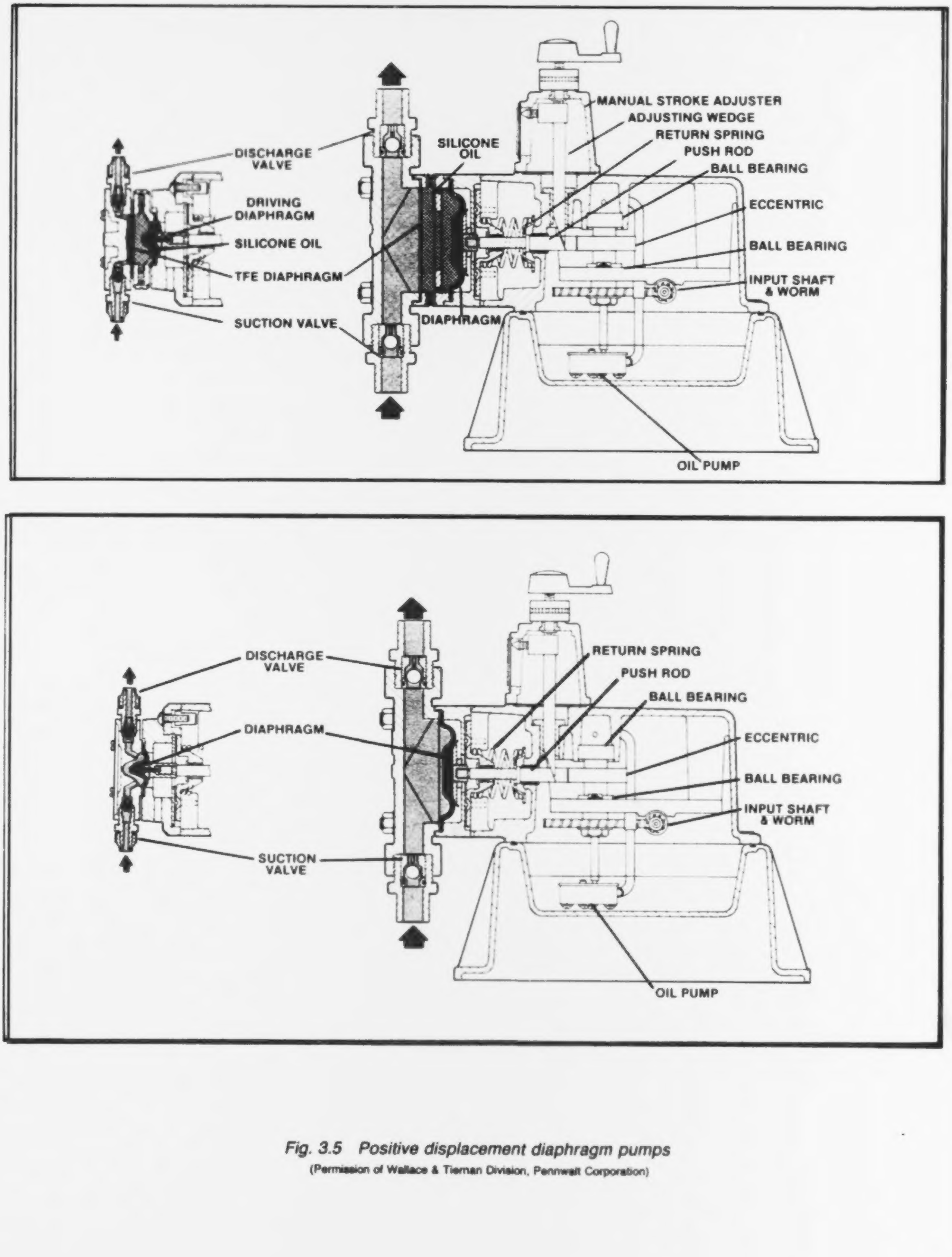

DISCHARGE VALVE
DRIVING DIAPHRAGM
SILICONE OIL
TFE DIAPHRAGM
SUCTION VALVE
SILICONE OIL
DIAPHRAGM
MANUAL STROKE ADJUSTER
ADJUSTING WEDGE
RETURN SPRING
PUSH ROD
BALL BEARING
ECCENTRIC
BALL BEARING
INPUT SHAFT & WORM
OIL PUMP
DISCHARGE VALVE
DIAPHRAGM
SUCTION VALVE
RETURN SPRING
PUSH ROD
BALL BEARING
ECCENTRIC
BALL BEARING
INPUT SHAFT & WORM
OIL PUMP

Fig. 3.5 Positive displacement diaphragm pumps

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

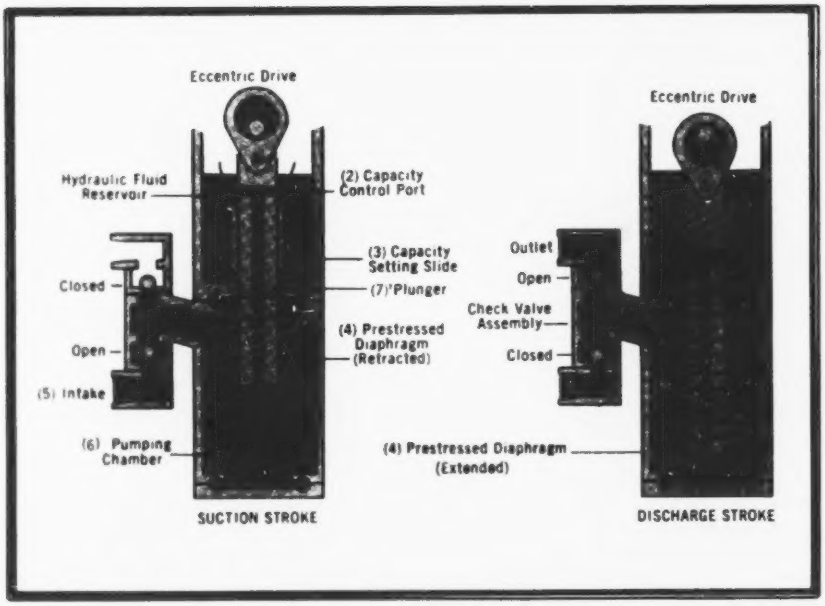

Eccentric Drive
Hydraulic Fluid Reservoir
(2) Capacity Control Port
(3) Capacity Setting Slide
Closed
(7) Plunger
Open
(4) Prestressed Diaphragm (Retracted)
(5) Intake
(6) Pumping Chamber
SUCTION STROKE
Eccentric Drive
Outlet
Open
Check Valve Assembly
Closed
(4) Prestressed Diaphragm (Extended)
DISCHARGE STROKE

Fig. 3.6 Positive displacement diaphragm metering

(Permission of BIF, a Unit of General Signal)

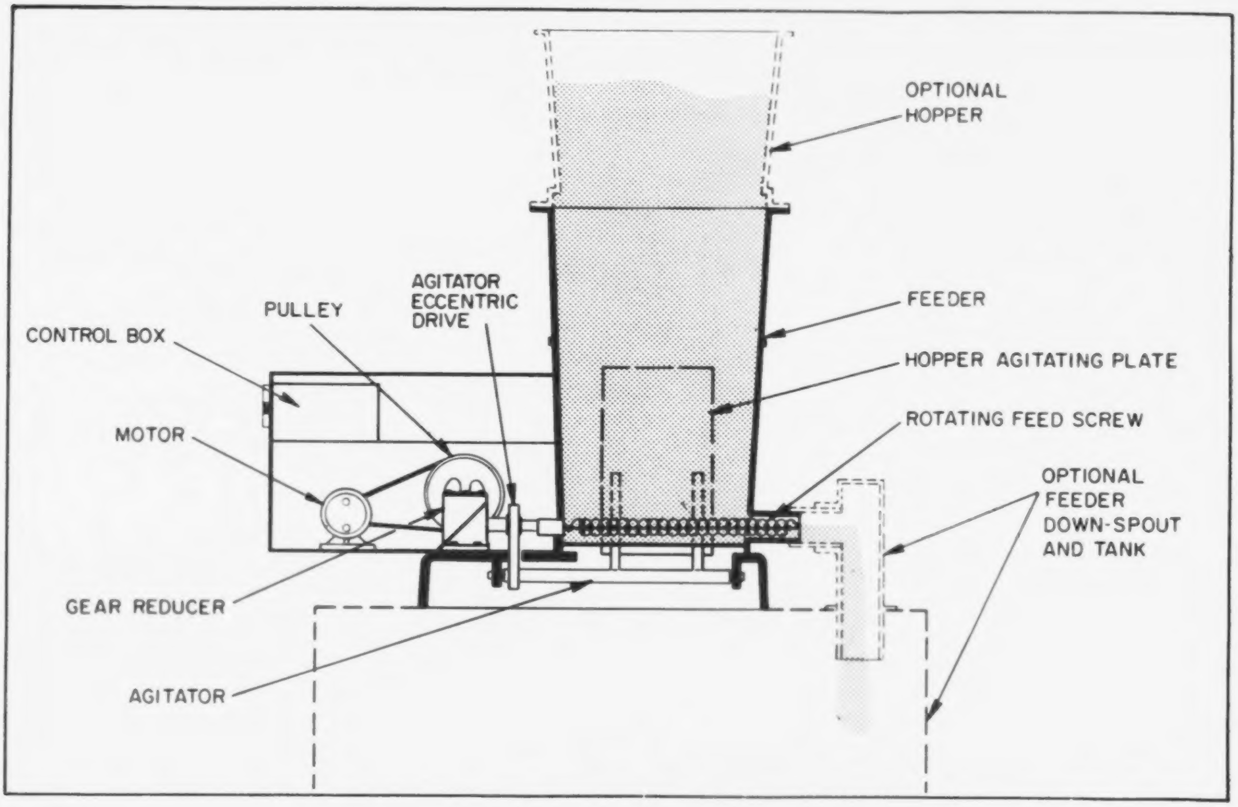

OPTIONAL HOPPER
FEEDER
HOPPER AGITATING PLATE
ROTATING FEED SCREW
OPTIONAL FEEDER DOWN-SPOUT AND TANK
AGITATOR ECCENTRIC DRIVE
PULLEY
CONTROL BOX
MOTOR
GEAR REDUCER
AGITATOR

Fig. 3.7 Volumetric screw feeder

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

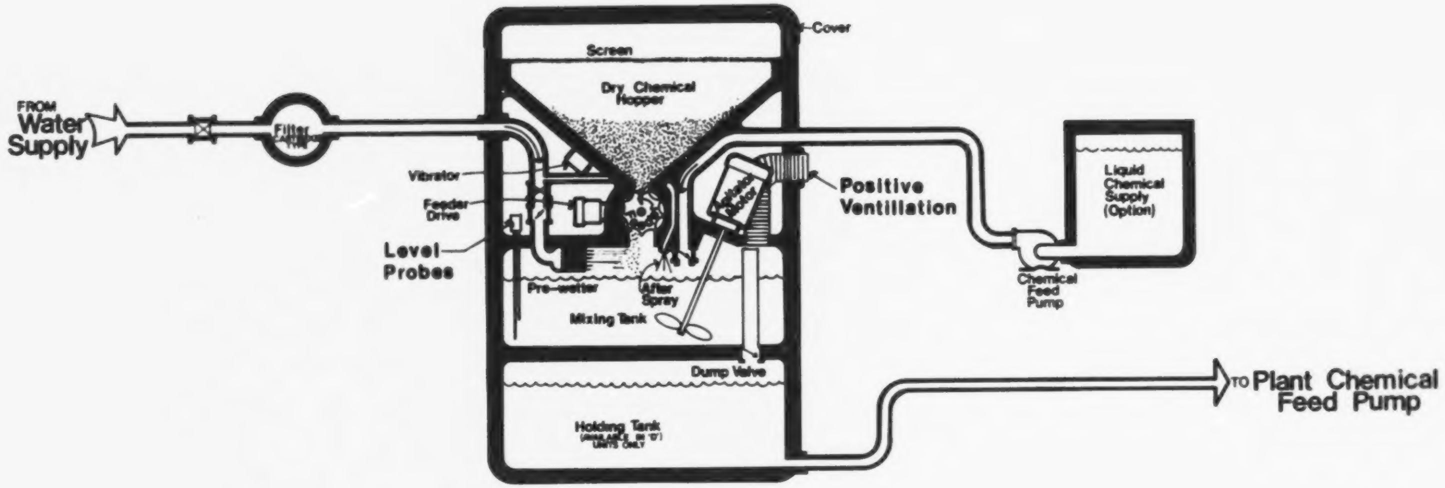

FROM
Water
Supply
Filter
Cover
Screen
Dry Chemical
Hopper
Vibrator
Feeder
Drive
Level
Probes
Pre-wetter
After
Spray
Mixing Tank
Positive
Ventillation
Liquid
Chemical
Supply
(Option)
Chemical
Feed
Pump
Dump Valve
Holding Tank
(AVAILABLE IN 'D'
UNITS ONLY
TO Plant Chemical
Feed Pump

Fig. 3.8 Rotary feeder

(Permission of Neptune Microfloc)

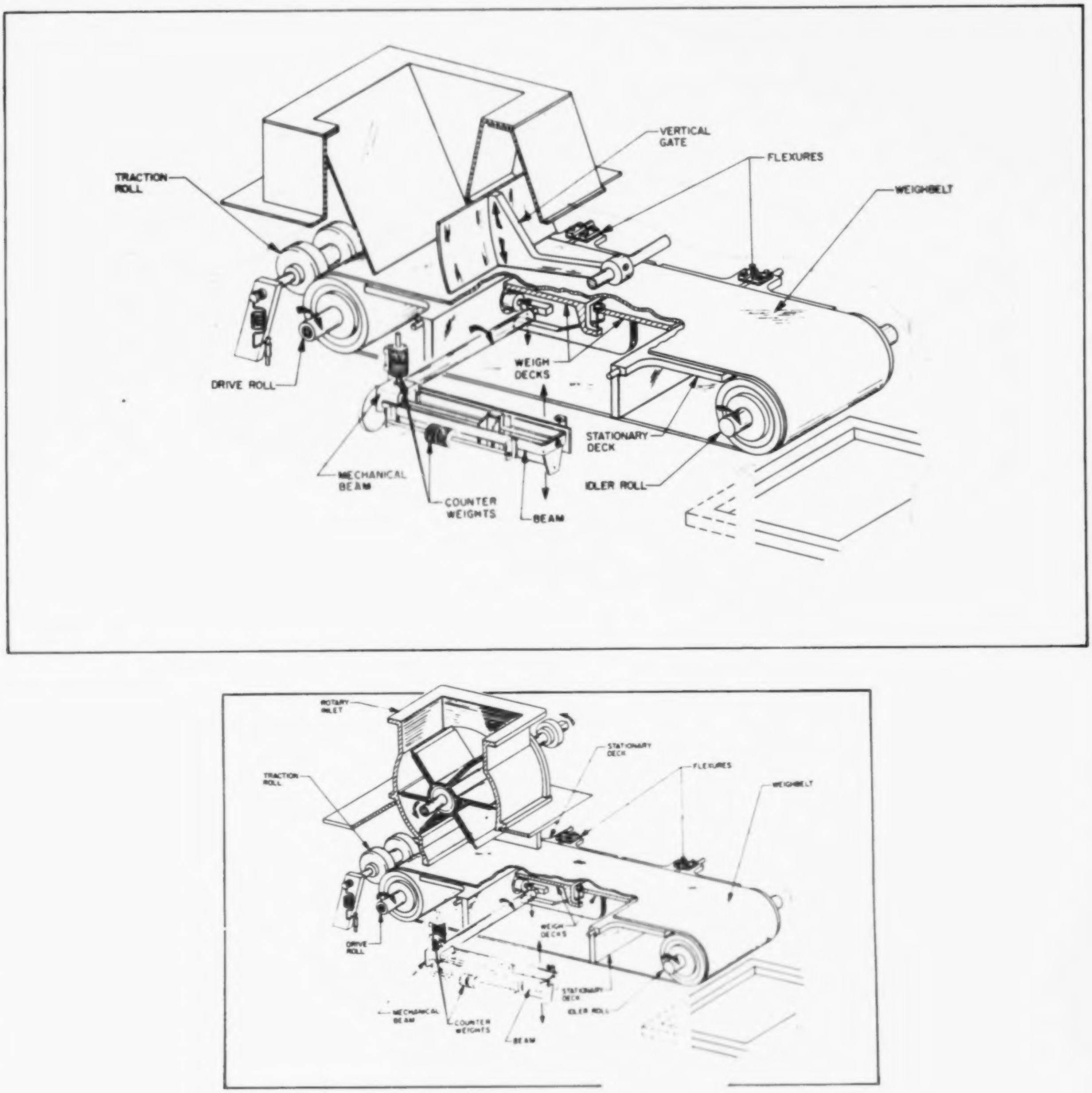

TRACTION ROLL
VERTICAL GATE
FLEXURES
WEIGHBELT
DRIVE ROLL
WEIGH DECKS
STATIONARY DECK
MECHANICAL BEAM
IDLER ROLL
COUNTER WEIGHTS
BEAM
ROTARY INLET
STATIONARY DECK
FLEXURES
TRACTION ROLL
WEIGHBELT
DRIVE ROLL
WEIGH DECKS
STATIONARY DECK
IDLER ROLL
MECHANICAL BEAM
COUNTER WEIGHTS
BEAM

Fig. 3.9 Gravimetric belt feeders

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

3.122 Reviewing Chemical Feed System Designs

When reviewing chemical feeding system designs and specifications, the operator should check the following items:

1. Review the results of pre-design tests to determine the chemical feed rate for both the present and future. The chemical feeders should be sized to handle the full range of chemical doses or provisions should be made for future expansion.
2. Determine if sampling points are provided to measure chemical feeder output.
3. Be sure provisions are made for standby equipment in order to maintain uninterrupted dosages during equipment maintenance.
4. Look for *ADEQUATE VALVING* to allow bypassing or removing equipment for maintenance without interrupting the chemical dosage.
5. Examine plans for valving to allow flushing the system with water before removing from service.
6. Be sure corrosion resistant drains are provided to prevent chemical leaks from reaching the floor; for example, drips from pump packing.
7. Check for corrosion-resistant pumps, piping, valves, and fittings as needed.
8. Determine amount of maintenance required. The system should require a minimum of maintenance. Equipment should be standard, with replacement parts readily available.
9. Consider the effect of changing head conditions, both suction and discharge, on the chemical feeder output. Changing head conditions should not affect the output if the proper chemical feeder has been specified.
10. Determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and record.

3.123 Chemical Feeder Start-Up

After the chemical feed system has been purchased and installed, the operator must carefully check it out before starting it up. Even if the contractor that installed the system is responsible for insuring that the equipment operates as designed, the operation by plant personnel, the functioning of the equipment, and the results from the process are the responsibility of the chief operator. Therefore, before start-up, check the following items:

1. Inspect the electrical system for proper voltage, for properly sized overload protection, for proper operation of control lights on the control panel, for proper safety lock-out switches and operation and for proper equipment rotation.
2. Confirm that the manufacturer's lubrication and start-up procedures are being followed. Equipment may be damaged in minutes if it is run without lubrication.
3. Examine all fittings, inspection plates and drains to assure that they will not leak when placed into service.
4. Determine the proper positions for all valves. A positive displacement pump will damage itself or rupture lines in seconds if allowed to run against a closed valve or system.
5. Be sure that the chemical to be fed is available. A progressive cavity pump will be damaged in minutes if it is allowed to run dry.
6. Inspect all equipment for binding or rubbing.
7. Confirm that safety guards are in place.
8. Examine the operation of all auxiliary equipment including the dust collectors, fans, cooling water, mixing water, and safety equipment.
9. Check the operation of alarms and safety shutoffs. If it is possible, operate these devices by manually tripping each one. Examples of these devices are alarms and shutoffs for high water, low water, high temperature, high pressure, and low chemical levels.
10. Be sure that safety equipment, such as eyewash, drench showers, gas masks, face shields, gloves and vent fans, is in place and functional.
11. Record all important nameplate data and place it in the plant files for future reference.

3.124 Chemical Feeder Operation

Once the chemical feed equipment is in operation and the major "bugs" are worked out, the feeder will need to be "fine tuned." To aid in fine tuning and build confidence in the entire chemical feed system, the operator must maintain accurate records (Figures 3.10 and 3.11). These records will include the flows and characteristics of the waste before treatment, the dosage and conditions of the chemical treatment, and the results obtained after treatment. A comment section should be used to note abnormal conditions, such as a feeder plugged for a short time, a sudden change in the characteristics of the influent waste, and related equipment that malfunctions. Daily logs should be summarized into a form that operators can use as a future reference.

3.125 Shutting Down Chemical Systems

If the equipment is going to be shut down for an extended length of time, it should be cleaned out to prevent corrosion and/or the solidifying of the chemical. Lines and equipment could be damaged when restarted if chemicals left in them solidify. Operators could be seriously injured if they open a chemical line that has not been properly flushed out.

The following items should be included in your checklist for shutting down the chemical system:

1. Shut off the chemical supply,
2. Run dry chemicals completely out of the equipment and clean equipment,
3. Flush out all the solution lines,
4. Shut off the electrical power,
5. Shut off the water supply and *PROTECT FROM FREEZING*, and
6. Drain and clean the mix and feed tanks.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

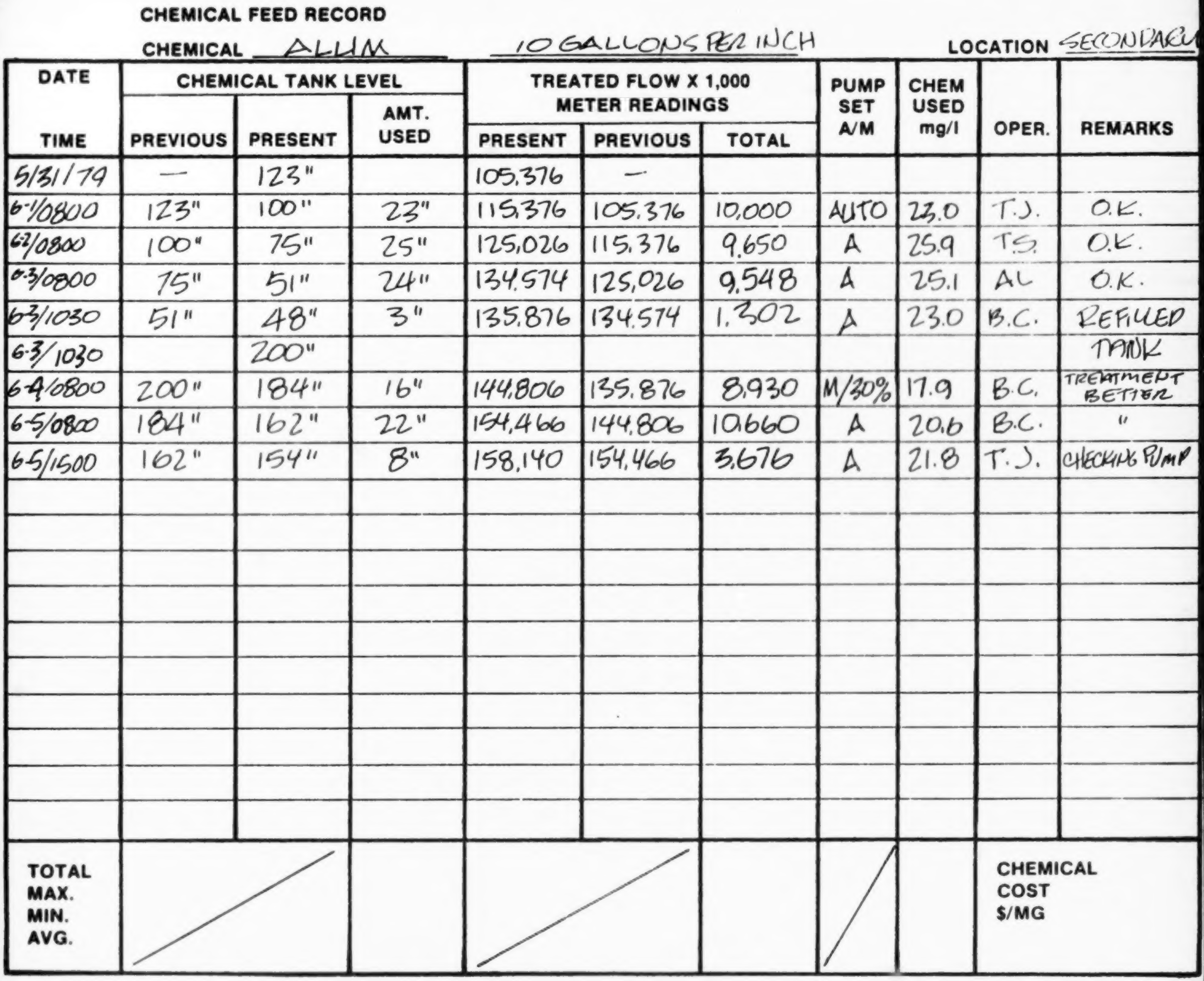
3.1L List the items that should be considered when selecting a chemical feeder.

3.1M What information should be recorded for a chemical feeder operation?

SODIUM HYDROXIDE LOG

	TANK #1 GAL.	TANK #2 GAL.	TANK #3 GAL.	GAL. #3 BEFORE TRANS.	GAL. #3 AFTER TRANS.	H_2O TO NAOH	DILUTE GAL. USED	TOTAL GAL REC.	REMARKS
1	880	-0-	1280				300		
2	880	-0-	990				290		
3	880	-0-	700				290		
4	880	-0-	580				120		
5	880	-0-	300				280		
6	-0-	-0-	1840	200	2000	1-1	260		
7	-0-	-0-	1600				240		
8	-0-	-0-	1400				200		
9	-0-	-0-	1240				160	4,000	
10	1990	1940	1050				190		
11	1990	1940	850				200		
12	1990	1940	650				200		
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									

Fig. 3.10 Typical record of chemical feeder operation



CHEMICAL FEED RECORD

CHEMICAL ALUM   10 GALLONS PER INCH   **LOCATION** SECONDAR

DATE TIME	CHEMICAL TANK LEVEL			TREATED FLOW X 1,000 METER READINGS			PUMP SET A/M	CHEM USED mg/l	OPER.	REMARKS
	PREVIOUS	PRESENT	AMT. USED	PRESENT	PREVIOUS	TOTAL				
5/31/79	—	123"		105,376	—					
6-1/0800	123"	100"	23"	115,376	105,376	10,000	AUTO	23.0	T.J.	O.K.
6-2/0800	100"	75"	25"	125,026	115,376	9,650	A	25.9	T.S.	O.K.
6-3/0800	75"	51"	24"	134,574	125,026	9,548	A	25.1	AL	O.K.
6-3/1030	51"	48"	3"	135,876	134,574	1,302	A	23.0	B.C.	REFILLED
6-3/1030		200"								TANK
6-4/0800	200"	184"	16"	144,806	135,876	8,930	M/30%	17.9	B.C.	TREATMENT BETTER
6-5/0800	184"	162"	22"	154,466	144,806	10,660	A	20.6	B.C.	"
6-5/1500	162"	154"	8"	158,140	154,466	3,676	A	21.8	T.J.	CHECKING PUMP
TOTAL MAX. MIN. AVG.									CHEMICAL COST $/MG	

Fig. 3.11 Typical form for chemical feeder operation

3.13 Determining Chemical Dosage

The proper chemical dosage is very important. A slight amount over or under the optimum is often worse than not adding chemicals at all. A combination of two or more chemicals will often result in improved treatment and reduced overall costs.

The wastewater entering the system may change composition from weekdays to weekends, from season to season, or from year to year. Because of these variations, the operator must carefully observe the efficiency of the chemical treatment.

When chemicals are added to reduce the effluent suspended solids, the operator should daily:

1. Run suspended solids tests on influent and effluent,
2. Calculate suspended solid removal efficiency,
3. Calculate chemical dosage,
4. Run turbidity tests on effluent,
5. Observe visual appearance of effluent, and
6. Maintain complete records.

3.130 Jar Test (Figure 3.12)

The most common method used to determine coagulation dosages is the jar test. The jar test is an attempt to duplicate plant conditions by using laboratory equipment. Jar tests can be misleading unless they reflect actual plant suspended solids conditions. Be sure to run jar tests on samples of the water to be treated. For example, a plant is adding metal salts for phosphorus removal and a polymer for suspended solids control to the effluent from an activated sludge aeration tank. Before the type of polymer and dose can be determined, you will have to build up the metal hydroxy phosphate precipitate in the activated sludge system to "steady-state" or "equilibrium" conditions.

Equal amounts of influent samples (usually 500 to 1,000 ml) to be treated are set up in a gang stirrer (Figure 3.12) for the jar test. Chemicals are added in varying doses and all portions of the sample are rapidly mixed. After rapid mixing, the samples are slowly mixed to approximate the conditions in the plant. Mixing is then stopped and the floc formed is allowed to settle. The appearance, the time to form a floc, and the settling conditions are recorded. The supernatant (liquid above the settled sludge) is analyzed for turbidity, suspended solids and pH. With this information the operator selects the best dosage to feed on the basis of clarity of effluent and minimum cost of chemicals.

3.131 Procedure for Plants Without Laboratory Facilities

Source: *PROCEDURE FOR DETERMINING THE ALUM DOSAGE* Permission of Industrial Chemicals Division, Allied Chemical Corporation, Solvay, New York

In case a laboratory is unavailable, it is possible to maintain reasonable control by conducting coagulation tests by means of a simple hand-stirring method.

Clear glass fruit jars, one- to two-quart capacity, are a good substitute for beakers and are easily obtainable. If necessary, the local druggist or high school chemistry teacher will usually assist in preparing alum solutions and lime suspensions. If a pipet is unavailable, a common medicine dropper will deliver approximately 20 drops to a ml. A calibrated dropper (1.0 ml) may be obtained from the drug store.

Procedure:

1. Dissolve 9.46 grams of alum and dilute to 1 liter (8.95 grams of alum to one quart). One ml of this solution will provide a treatment of 10 mg/*L* of alum when added to one quart (946 ml) of the water sample.
2. With the pipet or medicine dropper, add 1 ml of the alum solution to one quart of the sample and stir rapidly for approximately two minutes. Actual rapid mixing time should be similar to the actual detention time of the water being treated in the flash mixer. This actual detention time may vary from 50 seconds to six minutes depending on design and flows. Then stir gently for at least fifteen minutes to permit floc particles to grow. Again, this actual gentle mixing time should be similar to the actual process flocculation time. The speed of gentle mixing paddles in the jar test should be similar to the actual flocculator paddles. When running the jar test, try adjusting the paddle speed to produce the best floc particle growth and then operate the flocculator paddles at this speed. Under some conditions the best floc can be produced by stopping the flocculators. Avoid violent agitation during this floc conditioning stage to prevent the breakup of the floc particle.
3. Observe the quality of the floc, the rate of settling, and the clarity of the settled water.
4. Repeat the above using a higher alum dose until the desired floc and clarity are achieved.

Helpful Factors:

1 liter = 1000 ml
1 quart = 946 ml
1 grain/gal = 17.1 mg/*L*
1 grain/gal = 143 lbs/million gallons
1 mg/*L* = 8.34 lbs/million gallons

3.132 Phosphate Monitoring

When the coagulant is being used to precipitate phosphate as well as to remove solids, coagulant dosage control may be obtained by automatically analyzing the incoming wastewater for soluble orthophosphate. The coagulant feeder is set to maintain a selected ratio of coagulant-to-phosphate either automatically or manually. Equipment is available that will automatically do this type of coagulant feeding.

Coagulant dosages that produce good phosphate removal will generally produce good solids removal if polymers are used to aid in flocculating the fine, precipitated matter. Usually the polymer feed should be flow-paced; however, the polymer feeder may function with manual adjustments.

3.14 Good Housekeeping

Good housekeeping is a part of the total plant operation. Good housekeeping around the chemical feed systems is very important to good operations and safety. A dry chemical feeder that weighs its output will change its feed rate if chemicals are allowed to build up on the scales. Good housekeeping will reduce the hazard of slipping around chemical handling areas and will keep the dust down in work areas. Good housekeeping is a daily duty and must not be neglected.

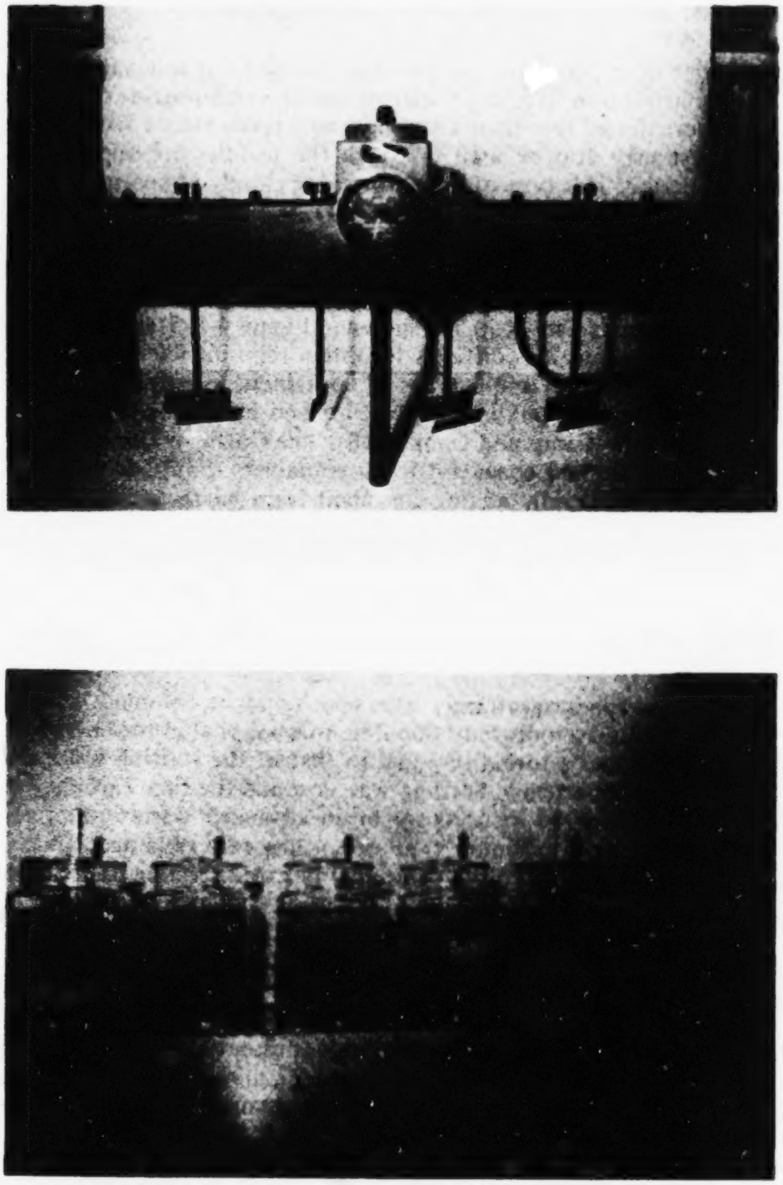


Fig. 3.12 Jar test units with mechanical (top) and magnetic (bottom) stirrers

(Source: EPA Process Design Manual for Suspended Solids Removal)

3.15 Safe Working Habits

Chemical feed equipment and chemical handling areas have safety hazards that each operator should become aware of for each plant. In addition to the usual electrical and mechanical hazards associated with automatic equipment, chemical feeding hazards include:

1. Strong acids,
2. Strong caustics,
3. High pressures,
4. High temperatures,
5. Dust in the air, and
6. Slippery walk areas.

Develop safe working habits by always wearing proper safety equipment and protective clothing.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.1N What factors can cause a change in chemical dose requirements?

3.1O How are coagulation dosages determined?

3.1P What is the jar test?

3.16 Operation

3.160 Operational Strategy

The development of an operational strategy for a chemical treatment process will prepare you to deal with sudden changes in the water being treated, to train new operators and to plan for the future. Items that should be considered in your strategy include:

1. The jar test is the most important control test for chemical treatment. Set up your laboratory so jar tests can be run quickly and easily. Accurate jar tests can result in significant chemical and cost savings. For example, if the dosage of a polyelectrolyte costing $2.00 per pound could be reduced by 0.5 mg/*L* in a 10 MGD plant, the cost savings would be $83.40 per day.
2. Monitor chemical feeders closely to assure proper output. New equipment should have actual feed rates measured and compared with feed settings at least weekly.
3. Adjust chemical dosages whenever the flow rate changes. Long detention times during low flows may not require as high a chemical dosage as shorter detention times during high flows.
4. Monitor water conditions and quality at least daily for alkalinity, pH, temperature, turbidity, and suspended solids because these water quality indicators may signal a need for a chemical dosage change. If you are removing phosphorous, measure soluble phosphorous also.
5. Consider in-plant conditions when collecting samples for jar tests and adjusting chemical dosages. For example, if one-half of the primary clarifiers in a plant are out of service or if a digester is upset, these situations can affect required chemical doses.

3.161 Abnormal Operation

This section contains a list of abnormal conditions that could occur at any time during the operation of a wastewater treatment plant. Included are recommendations that should help you adjust the chemical treatment system in order to maintain a high quality effluent.

1. High solids concentrations in effluent leaving the secondary clarifiers due to bulking sludge, rising sludge or solids washout.
   a. Inspect chemical feeders for proper output.
   b. Run jar tests to determine if dosage requirements have changed.
   c. Examine overall plant operations to locate cause of high solids.
   d. Increase sludge removal rates from clarifiers.
2. Low suspended solids in effluent leaving the secondary clarifiers.
   a. Inspect chemical feeders for proper output.
   b. Run jar tests to determine if dosage requirements have changed.
   c. Record in log book conditions and dosage that produced low solids in the effluent. You need to know how you produced a good quality effluent.
3. High flows passing through the treatment plant.
   a. Prepare to feed a greater quantity of chemicals.
   b. Run jar tests to determine dosage that will produce rapid settling rates because detention times are reduced.
   c. Be sure jar test flash mixing and flocculation times are similar to actual detention times through these units during the high flows.
4. Low flows passing through the treatment plant.
   a. Run jar tests to determine optimum dosage because longer detention times may allow a reduction in chemical dosage which will reduce chemical costs.
   b. Watch for chemical overdoses that could produce toxic conditions in biological treatment processes or in the receiving waters.
5. A change in the pH of the water being treated by one or more units.
   a. Inspect chemical feeders to determine if the chemicals being added are causing the pH change.
   b. Run jar tests to determine if chemical feed rates need adjusting.
   c. Extreme pH changes may affect biological activity and effectiveness of disinfection. Try to control chemical feeders to minimize chemical changes.
   d. If existing chemical dosages will not cause coagulation, new chemicals may be required. For example, you may have to switch from one type of polyelectrolyte to another type.

6. A change in water temperature resulting from seasonal weather conditions, groundwater infiltration and/or wet weather inflows.
   a. Run a jar test to determine if new chemical feed rates are required. Coagulation and settling rates change when the temperature changes.

3.162 Troubleshooting

PROBLEM: NO COAGULATION.

Inspect the following items:

1. Chemical feed pump operation,
2. Chemical supply and valve positions,
3. Solution carrier water flow and valve positions,
4. Applied water for a significant change,
5. Actual feeder output by catching a timed sample, and
6. Feed chemical strength.

Run a jar test to determine the proper dosage. Be sure the jar test chemicals are the proper strength.

PROBLEM: FOAMING.

Foam can develop in rapid-mix tanks and flocculators. Control foam by the use of water spray from hoses or surface spray nozzles.

3.17 Maintenance

All equipment maintenance must be performed in accordance with manufacturers' instructions. Good housekeeping is very important whenever working with chemicals. Chemical feed pumps and bottom sludge pumps must be periodically disassembled and cleaned. Weir plates, baffles and drains must be kept clean to maintain proper basin hydraulics. Weir crests must always be kept clean. Motors, drive systems and paddles will require servicing and repair. Frequency and type of maintenance and repair will depend on housekeeping, chemicals and equipment.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.1Q What water quality indicators should be monitored when operating a chemical treatment process?

3.1R What abnormal conditions could be encountered in the water being treated when operating a chemical treatment process?

3.1S List two problems that could occur when operating a chemical treatment process.

END OF LESSON 1 OF 4 LESSONS
ON
PHYSICAL-CHEMICAL TREATMENT

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 4 Lessons)

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

At the end of each lesson in this chapter you will find some discussion and review questions that you should answer before continuing. The purpose of these questions is to indicate to you how well you understand the material in this lesson. Write the answers to these questions in your notebook before continuing.

1. Why do some NPDES permits impose stringent discharge requirements on some treatment plants?
2. What precautions should be taken when using alum to improve the settling of solids?
3. Why should extensive laboratory testing be conducted before treating a secondary effluent with a polyelectrolyte to remove solids?
4. Why are positive displacement pumps used for metering chemicals?
5. What economic factors should be considered when selecting a chemical feeder?
6. Why should chemical feed equipment be cleaned before being shut down for an extended length of time?
7. Explain how to run the jar test.
8. Why should you develop an operational strategy for a chemical treatment process?

CHAPTER 3. PHYSICAL-CHEMICAL TREATMENT

(Lesson 2 of 4 Lessons)

3.2 SOLIDS REMOVAL FROM SECONDARY EFFLUENTS USING MICROSCREENS (Also see Chapter 6, Section 6.2, Screening and Microscreening Applied to Industrial Wastes)

Microstraining is a form of filtering used to clarify water by filtering out very small suspended solids. The process involves passing water through a very finely woven fabric called microfabric (Figure 3.13). Microfabric is usually made of stainless steel wire, plastic, polyester or nylon cloth. The polyester or nylon microfabric can be manufactured with openings as small as 1.0 microns (0.00004 inch) in size.

The filtered solids quickly build up a mat on the screen, thereby removing particles smaller than the actual openings of the fabric as the water passes through the mat.

The microfabric is attached to the outside of a drum. The applied water flows into the drum through one end and out through the wall (Figures 3.14 and 3.15). The solids remain inside the drum because they cannot pass through the microfabric. To prevent clogging of the microfabric, the drum is rotated and the mat of solids is washed off by a water spray system. The cleaned fabric rotates back into the process stream again in a continuous operation.

The solids are washed into a hopper inside the drum and carried back into the system for retreatment. These solids may be returned to the primary clarifier or they can be disposed of by thickening and pressing before ultimate disposal to landfill, incineration or byproduct recovery depending on the type of solids.

The process of microstraining is capable of:

1. Reducing the organic loading on the receiving waters,
2. Removing particles from the effluent,
3. Reducing the coliform group organisms in the water being treated,
4. Improving the effectiveness of the disinfectant,
5. Lowering the turbidity level, and
6. Improving the overall appearance of the effluent.

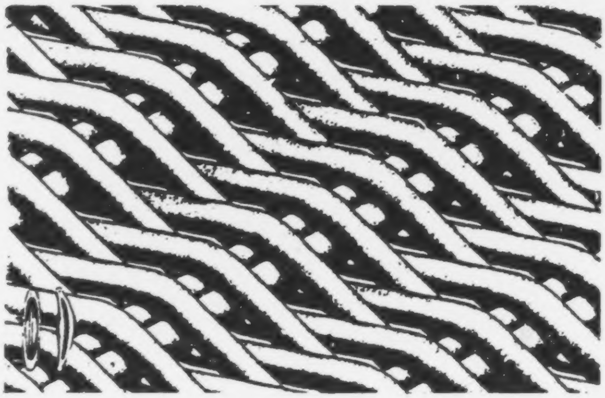


Fig. 3.13 Isometric drawing of microfabric with typical diatom shown against the fabric

(Permission of Crane Co.)

Important features of these units include:

1. They can be installed where space is limited,
2. They operate under open, gravity-flow conditions in concrete tanks or packaged steel tank units, and
3. They will operate with a minimal amount of manpower.

Microscreens added to existing treatment plants will affect other plant systems. The operator must be prepared to make the necessary adjustments to compensate for this problem. The solids leaving the plant in the effluent will be less; therefore the solids handling equipment will have an increased loading. This results in more sludge to pump, dewater, digest, and dispose of as a solid.

The water sprays cleaning the microfabric will add a flow load of from one- to five-percent of the influent flow to the treatment system.

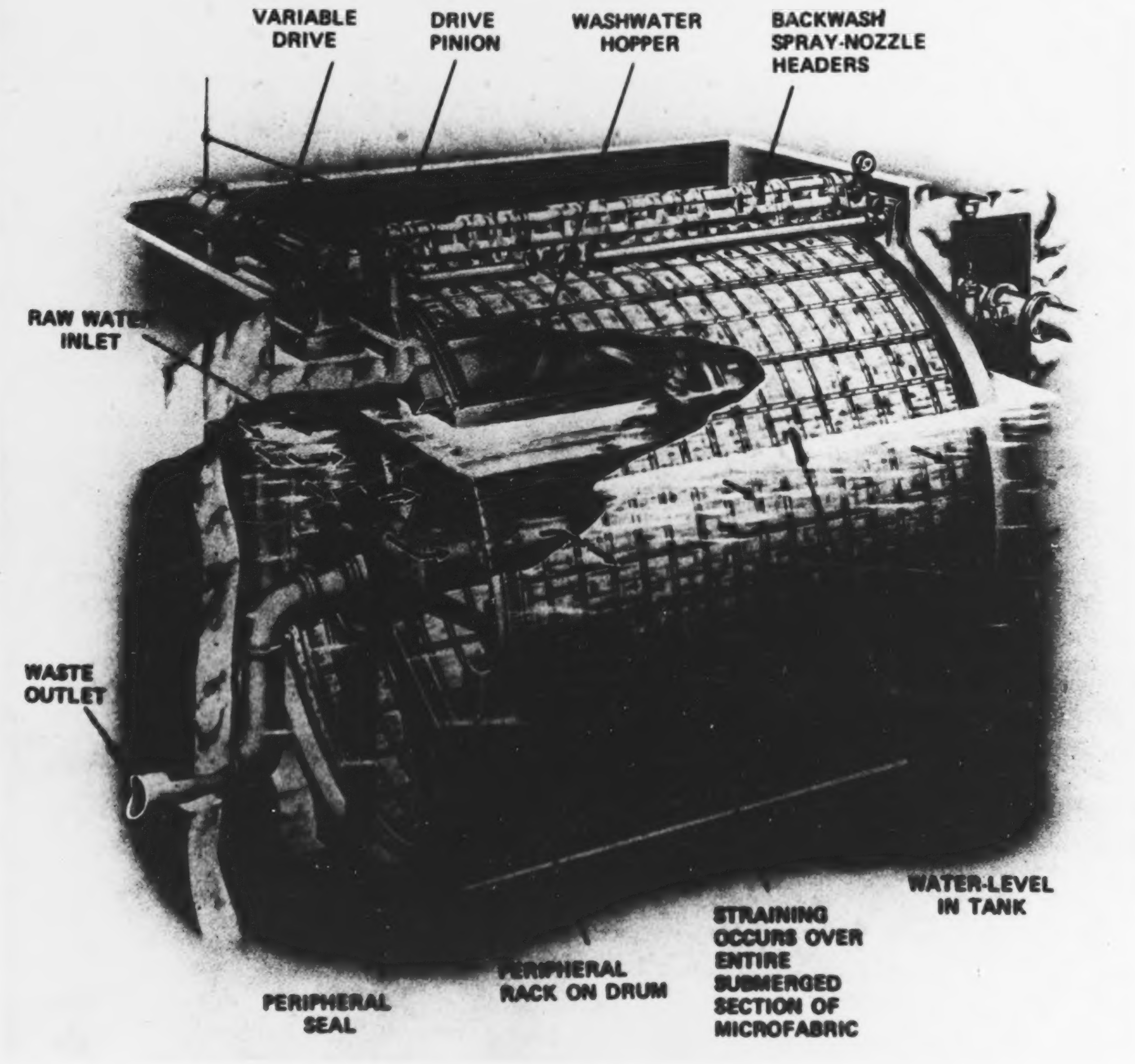

VARIABLE DRIVE
DRIVE PINION
WASHWATER HOPPER
BACKWASH SPRAY-NOZZLE HEADERS
RAW WATER INLET
WASTE OUTLET
PERIPHERAL SEAL
PERIPHERAL RACK ON DRUM
STRAINING OCCURS OVER ENTIRE SUBMERGED SECTION OF MICROFABRIC
WATER-LEVEL IN TANK

Fig. 3.14 Microscreen
(Permission of Crane Co.)

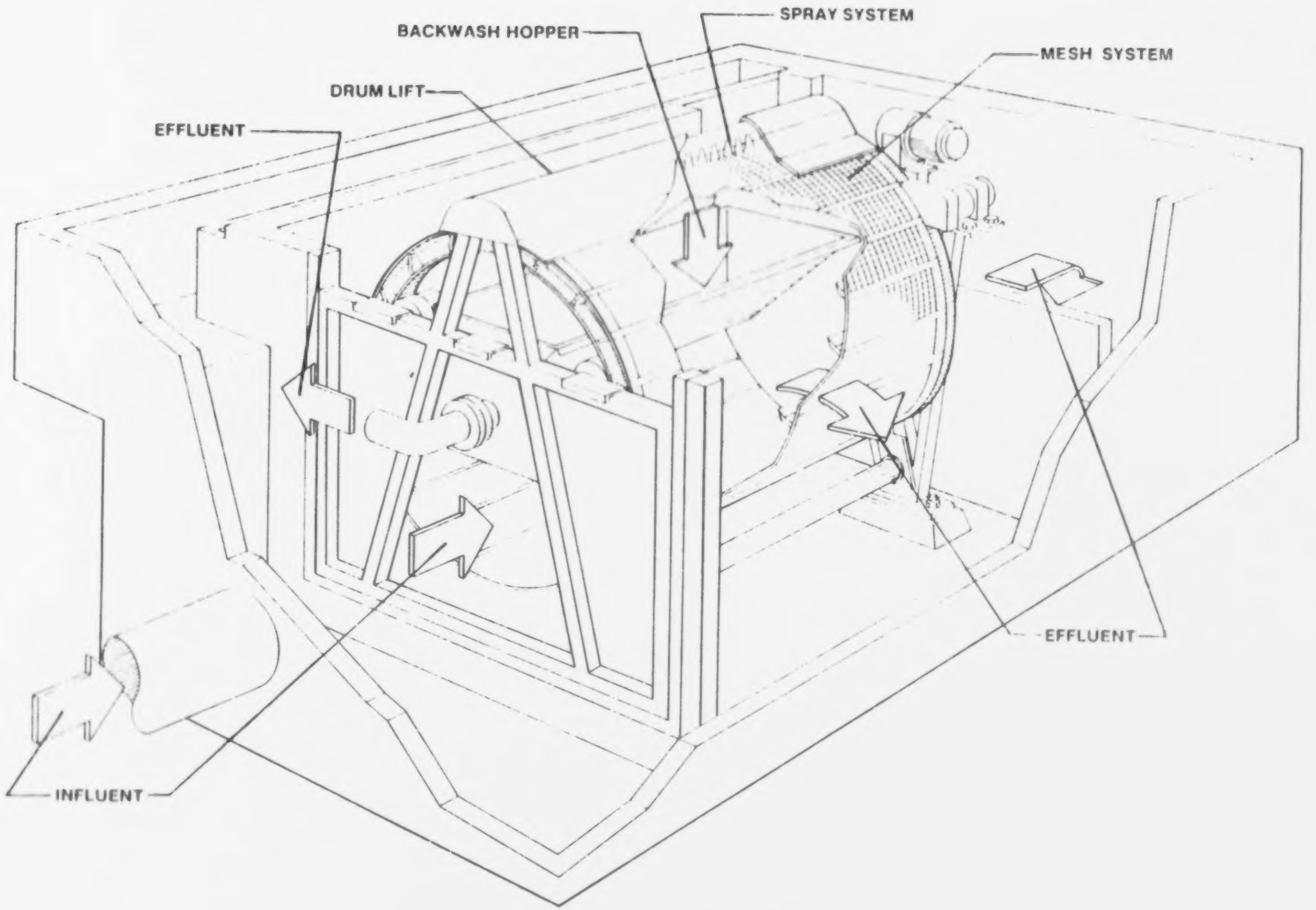

SPRAY SYSTEM
BACKWASH HOPPER
MESH SYSTEM
DRUM LIFT
EFFLUENT
EFFLUENT
INFLUENT

Fig. 3.15 Microscreen
(Courtesy of Zurn Industries, Inc.)

Plant staff may have to be increased to meet the need for additional labor to properly maintain and service microscreen units.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.2A What is microstraining?

3.2B What materials are generally used to manufacture microfabric?

3.20 Components of a Typical Microscreen

3.200 Drum

The drum is the main physical structure of the microscreen unit. This drum provides the frame around which the microfabric is attached. Drum diameters range from 5 to 10 feet (1.5 to 3.0 meters) in diameter and 1 to 10 feet (0.3 to 3.0 meters) in length. The drum operates with about 70 percent of its surface area submerged. This keeps a large area of the microfabric in the process flow.

3.201 Microfabric

The microfabric physically separates the solids from the water leaving the unit. The microfabric openings are extremely small. They are in the range of 1 to 60 microns. To get an idea of the size of an opening, a 60-micron fabric has about 60,000 openings per square inch and a 23-micron fabric has about 165,000 openings per square inch.

Microfabric is usually made of woven stainless steel or plastic. The plastic is used for the smaller openings and is less subject to chemical attack by chlorine or acid cleaning solutions. The stainless steel can better withstand steam cleaning used to remove grease and oil. Manufacturers will design and provide microfabric for each special application.

Microfabric is supplied either in small sections (8 in × 12 in or 20 cm × 30 cm) or in larger (18 in × 24 in or 45 cm × 60 cm) panels. The small sections are supported by and fastened directly to the drum frame while the panels have a supporting mesh of stainless steel bonded to the fabric.

Standard design calls for a 1 foot (30 cm) head loss at average flows and 2 feet (60 cm) head loss for normally expected maximum flows. Occasional peak head losses of 4 feet (120 cm) can be tolerated. One manufacturer indicates that stainless steel microfabric operated with a head loss of 3 inches (7.5 cm) under average conditions would have a life of 10 years; while the same fabric operated continuously at 24-inch (60 cm) head loss might last only 6 months.

Any flexing or movement of the fabric as it passes in and out of the process water will shorten its life. Chlorine in the process water and strong cleaning acid will also shorten the life of the microfabric.

3.202 Water Spray System

Water spraying on the outside of the drum as it reaches the highest point provides continuous backwashing of the microfabric. Water pressures ranging from 15 to 60 psi (1 to 4 kg/sq cm) are used with generally better results obtained using the higher pressures. Water consumption for backwashing varies from 1 to 5 percent of the flow through the filter.

3.203 Solids Waste Hopper

The hopper is located inside the revolving drum and catches the solids washed from the microfabric. Removed solids are returned to the primary treatment system and reprocessed or they may be disposed of by thickening and pressing before ultimate disposal to landfill, incineration or byproduct recovery.

3.204 Support Bearings

Support bearings may be water-lubricated axial or grease-lubricated bearings located on the upper inside surface of the rotating drum. Both types of bearings will allow the operating water level to be above the drum center line. These bearings require careful maintenance in accordance with the manufacturer's recommendations to prevent early failure.

3.205 Drum Drive Unit

The drum rotational speed may be adjusted manually or automatically in relation to the flow or head loss in the unit. Optimum speed will be determined with experience and usually does not require frequent adjustment.

3.206 Ultraviolet Lights

Ultraviolet (UV) lights are used to reduce biological growths on the microfabric. These growths can survive the water spray cleaning and will eventually clog the fabric. Ultraviolet lights reduce the manhours required to clean the microfabric with special washes. Ultraviolet light is *EXTREMELY* dangerous to the eyes. All plant staff must be aware of the dangers and protect their eyes.

3.207 Structure

The structure in which the microscreen unit is installed may be concrete or steel. Both need a good drain to permit easy dewatering and cleaning. A sloped bottom and a sump will aid in cleaning.

3.208 Bypass Weir

A bypass weir is needed to permit flows in excess of unit capacity to be bypassed. The manufacturer's recommended maximum head loss through the drum should never be exceeded to prevent damage to the microfabric.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.2C List the major components of a typical microscreen.

3.2D What is the purpose of ultraviolet lights used with a microscreening process?

3.21 Operation of Microscreens

3.210 Pre-Start Checklist

Before starting up any major piece of equipment, a thorough check of the system must be made to prevent damage to the equipment and injury to personnel. The following items should be included in your checklist for microscreens.

1. Be sure all debris from construction has been removed from the unit. Wood scraps and concrete chips can easily damage equipment, especially the microfabric.
2. Inspect the electrical installation for completeness. Be sure controls are properly covered, fuses properly sized, and proper safety lockouts have been installed.
3. Check motor and drives for proper alignment, for proper safety guards installed in place, and for free rotation of motor and drives.
4. Examine motors, drive units, bearings, and chain for proper lubrication.
5. Check motor for proper rotation.
6. Examine motor and drive unit for excessive vibration.
7. Study the operation of water sprays, ultraviolet lights and other auxiliary equipment for proper operation.
8. Inspect the entire unit for any safety hazards.

3.211 Normal Operation

Normal operation requires the operator to carefully follow the procedures outlined below.

1. Have the drum rotating when the process water first enters the microscreen or the fabric may plug and be damaged.
2. Open the inlet gates and start the drive motor, water sprays, lights and related equipment.
3. Maintain a log of the operation of the unit. Include the following items:
   a. Hours of operation,
   b. Volume of water processed, gallons or cubic meters,
   c. Rate of application, gpd or cu m/day,
   d. Applied suspended solids and BOD, lbs or kg/day,
   e. Effluent suspended solids and BOD, lbs or kg/day,
   f. Percent removal of suspended solids and BOD, %,
   g. Chemicals added, pounds or kilograms,
   h. Head loss through the screen, inches or centimeters,
   i. Maintenance performed on the unit, and
   j. Remarks of special observations.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.2E Before starting a microscreen unit, what items would you inspect in the electrical installation?

3.2F What items should be included in the log of the operation of a microscreen?

3.212 Abnormal Operation

When operating a microscreen, be prepared to solve problems created by the abnormal conditions listed in this section.

PROBLEM: HIGH FLOWS

Problems caused by high flows include:

1. Excessive head loss (above 12 inches or 30 centimeters) through the microscreen (be sure to check manufacturer's recommendations),
2. Excessive solids in the microscreen effluent,
3. Plugging of the microfabric with solids and/or grease, and
4. Untreated water overflowing the microscreen bypass weir.

SUGGESTED CORRECTIVE ACTION

1. Increase the drum rotation speed.
2. Increase the water spray pressure.
3. Place additional units in service.
4. Hand clean the microfabric with a bactericide, hot water or steam.
5. Reduce the flow by using a *FLOW-EQUALIZATION SYSTEM*[7] or by storing the excess flow in the influent line until the flows drop.
6. Add chemicals to upstream processes to reduce the suspended solids loading by improving settling.

PROBLEM: LOW APPLIED WATER FLOWS

Problems caused by low applied flows include:

1. Lower suspended solids loadings, and
2. Thinner mat buildup on microfabric. This thinner mat may reduce filtering effectiveness.

SUGGESTED CORRECTIVE ACTION

1. Reduce the drum rotation speed.
2. Reduce the water level within the microscreen.
3. Remove some of the microscreen units from operation (if you have more than one on line) to maintain design flows to units in service.

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[7] ***Flow-equalization system.** A device or tank designed to hold back or store a portion of peak flows for release during low-flow periods.*

PROBLEM: HIGH SOLIDS LOADING

Problems caused by high solids loadings include:

1. Excessive head loss (above 12 inches or 30 centimeters) through the microscreen (be sure to check manufacturer's recommendations),
2. Excessive solids in the microscreen effluent,
3. Plugging of the microfabric with solids, and
4. Untreated water overflowing the microscreen bypass weir.

SUGGESTED CORRECTIVE ACTION

Use same action as suggested to solve problems created by high flows.

PROBLEM: HIGH OR LOW pH LEVELS

Problems caused by high or low pH levels include:

1. A high pH may result in the buildup of mineral deposits that will plug the holes on the microfabric.
2. A rapid change in pH may upset upstream treatment processes, thus increasing the suspended solids loadings applied to the microscreen.
3. A low pH may result in the corrosion of metal, especially the microfabric.

SUGGESTED CORRECTIVE ACTION

1. If rapid pH changes are occurring, monitor the plant influent and chemically adjust the pH as necessary to maintain the pH within desired levels. Attempt to correct the cause of the pH changes at the source.
2. Adjust the pH chemically to a balanced relationship with the alkalinity and temperature to prevent corrosion or scaling (use of Langelier Saturation Index)[8].
3. Divert abnormal pH flows into a flow-equalization system and return these flows slowly by intermixing them with the normal flows.
4. Remove mineral scaling from the microfabric with a mild acid wash.

PROBLEM: HIGH CONCENTRATIONS OF OIL AND GREASE

Problems caused by high concentrations of oil and grease include:

1. Plugging of the microfabric;
2. When the microfabric is plugged, there will be a high head loss through the unit, reduced flow through, and ineffective cleaning of the fabric by the water sprays.
3. Untreated water may overflow the microscreen bypass weir.

SUGGESTED CORRECTIVE ACTION

1. Reduce oil and grease loadings at the source.
2. Improve effectiveness of oil and grease removal equipment.
3. Add chemicals to improve oil and grease removals.
4. Increase the drum rotation speed.
5. Increase the water spray pressure.
6. Place additional microscreens in service.
7. Clean the microfabric with hot water, steam or chemicals.

3.213 Operational Strategy

The development of an operational strategy for a microscreening process treating wastewater will aid in dealing with situations such as sudden changes in applied water, training new operators or planning for the future. This section lists items for you to consider when developing your own operational strategy.

1. Maintain the filtering rates within the design limits.
2. Adjust the drum rotational speed as needed to compensate for extreme flow or suspended solids loadings.
3. Monitor and log head loss and flow rates daily because of an increasing head loss may indicate incomplete cleaning of the microfabric by the water spray system.
4. If the applied suspended solids load is increasing greatly due to poor settling in an upstream process, add chemicals to improve settling.
5. Be prepared to clean the microfabric manually if plugging occurs.
6. To increase the life of the microfabric, do not apply chlorine to the wastewater being treated at a location upstream from the microscreen.

3.214 Shutdown of Microscreen

The microscreen should not be left standing in dirty water. If the unit is to be left out of service for a week or longer, the tank should be drained and the microfabric cleaned. This will prevent clogging from solids drying on the fabric and also prevent slimes from growing in the portion underwater.

When a unit is shut down, complete these steps:

1. Shut off the applied water flow.
2. Allow the water to filter out of the drum.
3. Drain the microscreen structure.
4. Clean the fabric with water sprays.
5. Hose down the sump.
6. Hose down the trough.
7. Shut off the water sprays.
8. Shut off the drive unit.
9. Shut off the ultraviolet lights.

When treating wastewaters of typical strength and pH, corrosion usually is not a serious problem. If chlorine has been applied to the wastewater, corrosion can be a problem.

3.215 Troubleshooting

PROBLEM: POOR SUSPENDED SOLIDS REMOVAL

1. Check the hydraulic load. Performance is better at lower hydraulic loads. How does the flow compare with design flow?
2. Inspect the upstream units. Increased suspended solids loading to the microscreen will result in increased effluent suspended solids.

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[8] *If you wish to use this method, consult a textbook on sanitary engineering or water treatment.*

3. Determine the drum speed. At lower drum speeds a thicker mat of solids can build up and provide better straining.
4. Look for excessive turbulence upstream. Breaking up of the flocculated particles at the microscreen influent will result in poorer suspended solids removal.
5. Check for pin floc carry-over from the upstream secondary clarifiers. Pin floc will result in a poor quality effluent even if the microscreen is operating properly because of the difficulty of removing pin floc.

PROBLEM: HIGH HEAD LOSS THROUGH MICROSCREEN

1. Determine the drum rotation speed. If drum is rotating too slowly, the mat will become too thick and produce a high head loss.
2. Inspect the upstream units. Increased suspended solids loadings will result in a rapid buildup of the solids mat.
3. Examine the water spray system for clogging of nozzles.
4. Determine the pressure in the water spray system. A higher pressure may be needed.
5. Look for a buildup of iron, manganese or grease on the microfabric. The fabric may need a special cleaning with acid, steam or hot water.

PROBLEM: POOR SOLIDS REMOVAL AND LACK OF HEAD LOSS

1. Look for damaged or torn microfabric.
2. Inspect for improperly installed microfabric panel.
3. Check for damaged end seal on the drum.
4. Look for plugged or inoperative head loss indicator.

3.22 Maintenance of Microscreen

As with all equipment, the operator must read the manufacturer's recommendations and follow them as they pertain to each installation. The following maintenance points should be considered:

1. Lubricate bearings, chains, and drive units as recommended.
2. Wash down daily and maintain good housekeeping practices.
3. Dewater sump monthly (or as needed) and remove solids and debris.
4. Inspect microfabric condition monthly.
5. Clean algae and slime growth with chlorox or bactericidal soap.
6. Clean grease and oil from microfabric with hot water or steam. *CAUTION.* Do not clean *PLASTIC* microfabric with steam. Use only hot water (120°F or 49°C) to remove grease. Steam may damage plastic microfabric.

3.23 Safety

Always think safety when working around mechanical equipment. Lock out and tag the drive units before working on the motor, the drive units, the drum or any electrical system.

When cleaning with an acid wash or a chlorine solution, wear protective clothing. This includes rubber aprons, rubber gloves and boots, and face shield and eye goggles if splashing of the chemical may occur.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 168.

3.2G What kinds of abnormal conditions could you encounter when operating a microscreen?

3.2H What problems are caused by high or low pH levels when operating a microscreen?

END OF LESSON 2 OF 4 LESSONS
ON
PHYSICAL-CHEMICAL TREATMENT

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 4 Lessons)

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 1.

9. How do microscreens remove particles smaller than the actual openings of the fabric?
10. What is the impact of microscreens on the solids handling facilities of a treatment plant?
11. Why is a pre-start inspection important before starting any major piece of equipment?
12. What operational action would you consider taking if a microscreen had to handle higher-than-design flows and solids loading?

CHAPTER 3. PHYSICAL-CHEMICAL TREATMENT

(Lesson 3 of 4 Lessons)

3.3 SOLIDS REMOVAL FROM SECONDARY EFFLUENTS USING GRAVITY FILTERS

3.30 Gravity Filters

3.300 Use of Filters

Gravity filtration is second only to gravity sedimentation for the separation of wastewater solids. This same process, using deep-bed filtration and granular media, has long been used in municipal and industrial water supplies. However, these systems are more frequently used for domestic water supplies that have much lower suspended solids concentrations than found in the effluent from secondary wastewater treatment plants.

3.301 Description of Filters

Applied water generally flows through wastewater filters from top to bottom. The applied water is distributed evenly over the surface of the filter media thru an inlet distribution system. This may be the same system as that used to uniformly collect the dirty backwash water.

The water travels through the filter media where the solids are trapped. The filter bed may be made up of one or several materials and/or several grades of materials. This is determined by the designer based primarily upon the quality of the applied water.

The underdrain system is designed to collect the filtered water uniformly throughout the bed. It also is used to uniformly apply the backwash water during backwashing. The system design must prevent the filter media from passing into the underdrain system, thereby being lost from the bed.

A surface wash system is beneficial during backwashing to scrub the surface mat, thus breaking it up with minimum amounts of water. In some installations air is used in place of surface washing as a means of breaking up the accumulated solids.

Valves control the volume, direction and duration of flows through the unit.

Instruments are used to monitor and record the volumes and quality of the water being processed through the filtering system.

3.302 Filtering Process

Water to be treated enters at the top of the filter bed through an inlet valve and is distributed over the entire filter surface. The water passes evenly down through the media (sand) and leaves the solids behind. Filtered water then travels out the bottom of the filter and into the underdrain collection system which is designed to uniformly collect the flow. Once inside the underdrain collection system, the water passes through a flow meter and rate-control valve. The rate-control valve maintains the desired flow through the filter and prevents backwash water from entering the filtered water during backwashing.

Most filters operate on a batch basis whereby the filter operates continuously until its capacity to remove solids is reached. At this time it is completely removed from service and cleaned. Other designs are available that filter continuously with a portion of the media always undergoing cleaning. The cleaning of the media may take place either externally or in place.

3.303 Backwashing Process

As suspended solids are removed from water, the filter media becomes clogged. This is indicated by a head loss reading. Through operating experience, the maximum head loss before backwashing will be determined. The filter should be backwashed after the solids capacity of the media has been met, but before solids break through into the effluent.

Backwashing consists of closing valves to stop influent flow and to protect the filtered water. Backwash water either flows by gravity or is pumped to the filter. This water flows through the underdrain system and back through the media. As the water flows through the media, the sand particles are lifted and are cleaned by rubbing against each other. The solids retained by the media are washed away with the backwash water and the media has been cleaned.

If the media is cleaned externally, the media is removed from the filter bed, cleaned in a separate system and recycled back into the bed. In-place cleaning involves washing a small section of the filter bed with a traveling backwash water or air-pulsing system while the remainder of the bed remains in service.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3A When should a gravity filter be cleaned?

3.3B Do most filters operate on a batch or on a continuous basis?

3.31 Methods of Filtration

3.310 Filter Types

Most filters used in wastewater treatment are "rapid sand" filters (Figure 3.16). They also may be called "downflow" (water flows down through the bed) or "static bed" (bed does not move or expand when filtering). These filters operate continuously until they must be shut down for backwashing. Other designs, such as the upflow and the biflow, are on the market. Both of these designs are attempts to use more of the filter media, thereby removing and holding more solids per filter run.

In the upflow filter (Figure 3.17), water enters the bottom and is removed from the top. The biflow system has water applied at both the top and bottom and water is withdrawn from the interior of the bed. Filters are always backwashed in an upflow direction regardless of the operating flow direction.

3.311 Surface Straining

Downflow filters are designed to remove suspended solids by either the surface-straining method or the depth-filtration method. In surface straining the filter is designed to remove the solids at the very top of the media. The fine grade-sized media is uniform throughout the bed. Because of this conformity, surface-straining systems will have a rapid head loss buildup, short filter runs, and they must be backwashed frequently. There are, however, no problems with breakthrough of solids. The solids compress into a mat at the surface which aids in removing solids; however, the mat is difficult to remove during backwashing. Backwashing, although needed more frequently, requires less water per wash than does a depth-filtration system.

3.312 Depth Filtration

Depth filtration is designed to permit the solids to penetrate deep into the media, thereby capturing the solids within as well as on the surface of the media. Depth filtration will have a slower buildup of head loss, but solids will break through more readily than with surface straining.

To reduce breakthrough, yet retain depth filtering, the multi-media design is used. This combines a fine, denser media (sand) on the bottom with a coarse, lighter media (anthracite coal) on the top (Figure 3.18). The coarse media remove large solids that would quickly clog finer media. The fine media will surface-strain solids that penetrate the full depth of the coarse media bed thereby preventing a breakthrough of solids. The filter is designed to prevent the fine media from escaping unless the head loss becomes too great.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3C What is meant by the following terms that are used to describe "rapid sand" filters?

1. Downflow
2. Static bed

3.3D From what part of the filter are solids removed by

1. Surface straining?
2. Depth filtration?

3.32 Location of Filters in a Treatment System

In wastewater treatment, the filters may be used in the following modes (Figure 3.19):

1. To polish secondary effluent without the addition of chemicals as filter aids just ahead of the filters,
2. To polish secondary effluent with the addition of chemicals as filter aids just ahead of the filters,
3. To polish secondary effluent that has been chemically pretreated and settled, and
4. To polish raw wastewater that has undergone coagulation, flocculation and sedimentation in a physical-chemical treatment system.

3.33 Major Parts of a Filter System (Figure 3.20)

This section describes the major parts of a filtering system and also how each part works or functions during the filtration process.

3.330 Inlet

The filter inlet gate allows the applied water to enter the top of the filter media. When closed it will permit emptying the filter for backwashing or maintenance.

3.331 Filter Media

The filter media selection is one of the most important design considerations. Filter beds are made up of silica sand, anthracite coal, garnet or ilmenite. Garnet and ilmenite are commonly used in multi-media beds.

Because of rapid plugging, the conventional single-media filter bed commonly used in potable water systems is generally unsatisfactory in removing solids from wastewater.

To lengthen filter runs and use the full bed depth, the dual- and multi-media filters are used. A layer of coarse media (anthracite) is placed over finer, dense material (sand or garnet). The coarse layer allows deep penetration of the solids into the bed causing a minimum of head loss. The fine material prevents breakthrough of solids into the effluent.

3.332 Filter Underdrains (Figure 3.21)

The filter underdrain system is designed to contain the filter media within the bed and to maintain uniform water flows through the entire bed during both filtering and backwashing.

3.333 Filter Media Scouring

If the filter media is not cleaned thoroughly at each backwashing, a buildup of solids will occur. The end result of incomplete cleaning is the formation of "mud balls" within the bed. These mud balls settle to the filter bottom and in time require rebuilding the entire bed. "Surface wash" and "air scour" are two systems used to improve cleaning of the media.

The surface wash system consists of either fixed or rotating nozzles installed just above the media. During a backwash, the bed expansion places the nozzles within the media where high-pressure water jetting out of the nozzles will agitate and clean the surface. Because these wash systems are designed primarily to break up the surface mat, deep filtering beds need nozzles placed deeper within the media.

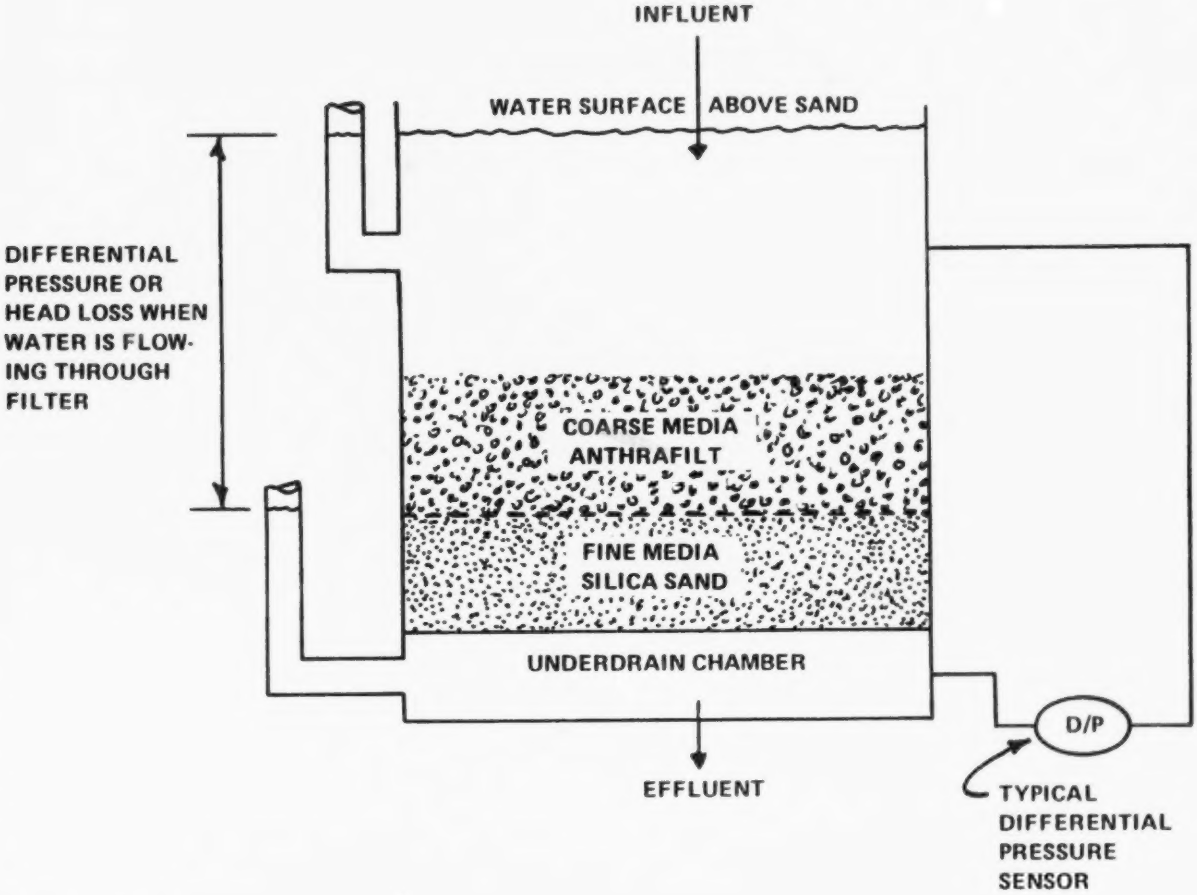

INFLUENT
WATER SURFACE ABOVE SAND
DIFFERENTIAL PRESSURE OR HEAD LOSS WHEN WATER IS FLOWING THROUGH FILTER
COARSE MEDIA ANTHRAFILT
FINE MEDIA SILICA SAND
UNDERDRAIN CHAMBER
EFFLUENT
D/P
TYPICAL DIFFERENTIAL PRESSURE SENSOR

Fig. 3.16 Differential pressure through a sand filter

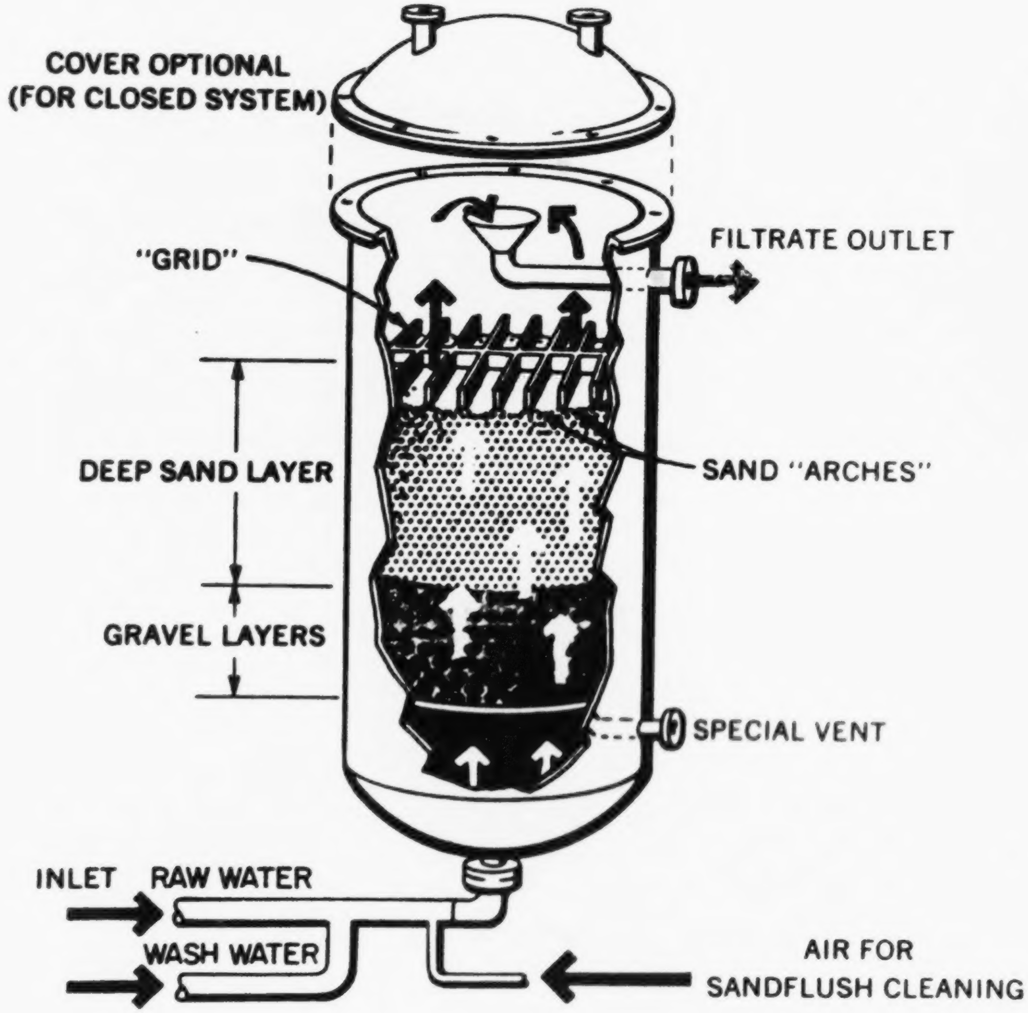
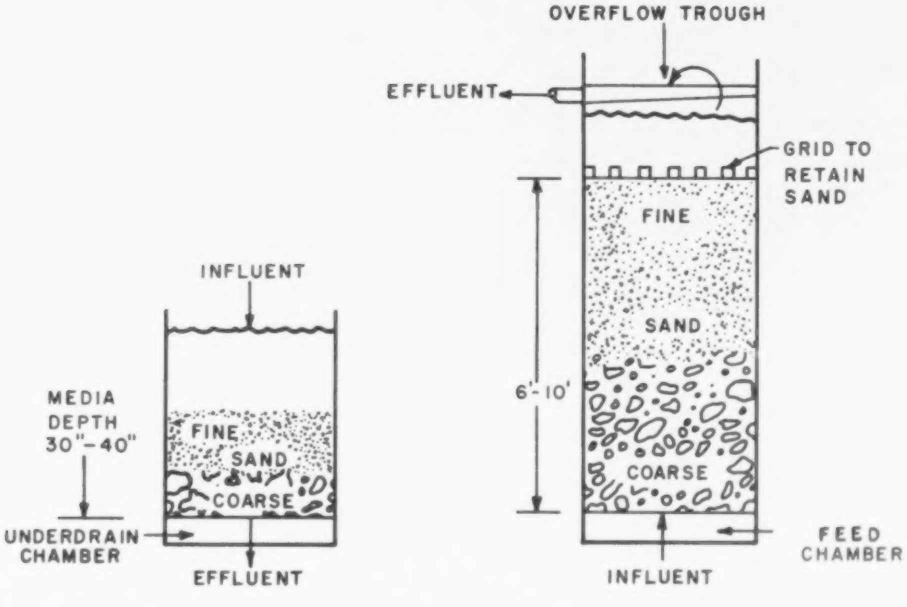

COVER OPTIONAL
(FOR CLOSED SYSTEM)
FILTRATE OUTLET
"GRID"
DEEP SAND LAYER
SAND "ARCHES"
GRAVEL LAYERS
SPECIAL VENT
INLET
RAW WATER
WASH WATER
AIR FOR
SANDFLUSH CLEANING

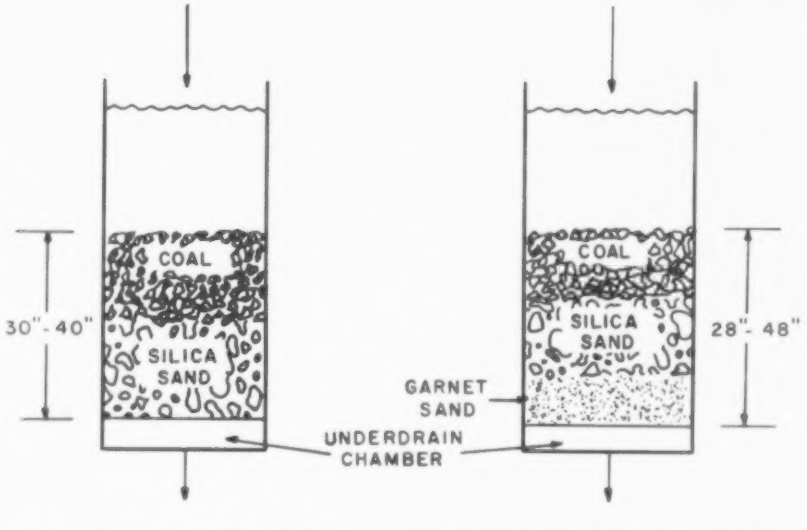
Fig. 3.17 Cross section of upflow filter

(Source: EPA Process Design Manual for Suspended Solids Removal)


OVERFLOW TROUGH
EFFLUENT
GRID TO RETAIN SAND
INFLUENT
MEDIA DEPTH 30"–40"
FINE
SAND
COARSE
UNDERDRAIN CHAMBER
EFFLUENT
6'-10'
FINE
SAND
COARSE
FEED CHAMBER
INFLUENT

(a) CONVENTIONAL DOWNFLOW FILTER

(b) UPFLOW FILTER


30"-40"
COAL
SILICA SAND
COAL
SILICA SAND
28"-48"
GARNET SAND
UNDERDRAIN CHAMBER

(c) DUAL-MEDIA DOWNFLOW FILTER

(d) MULTI-MEDIA DOWNFLOW FILTER

Fig. 3.18 Filter configurations

(Source: EPA Process Design Manual for Suspended Solids Removal)

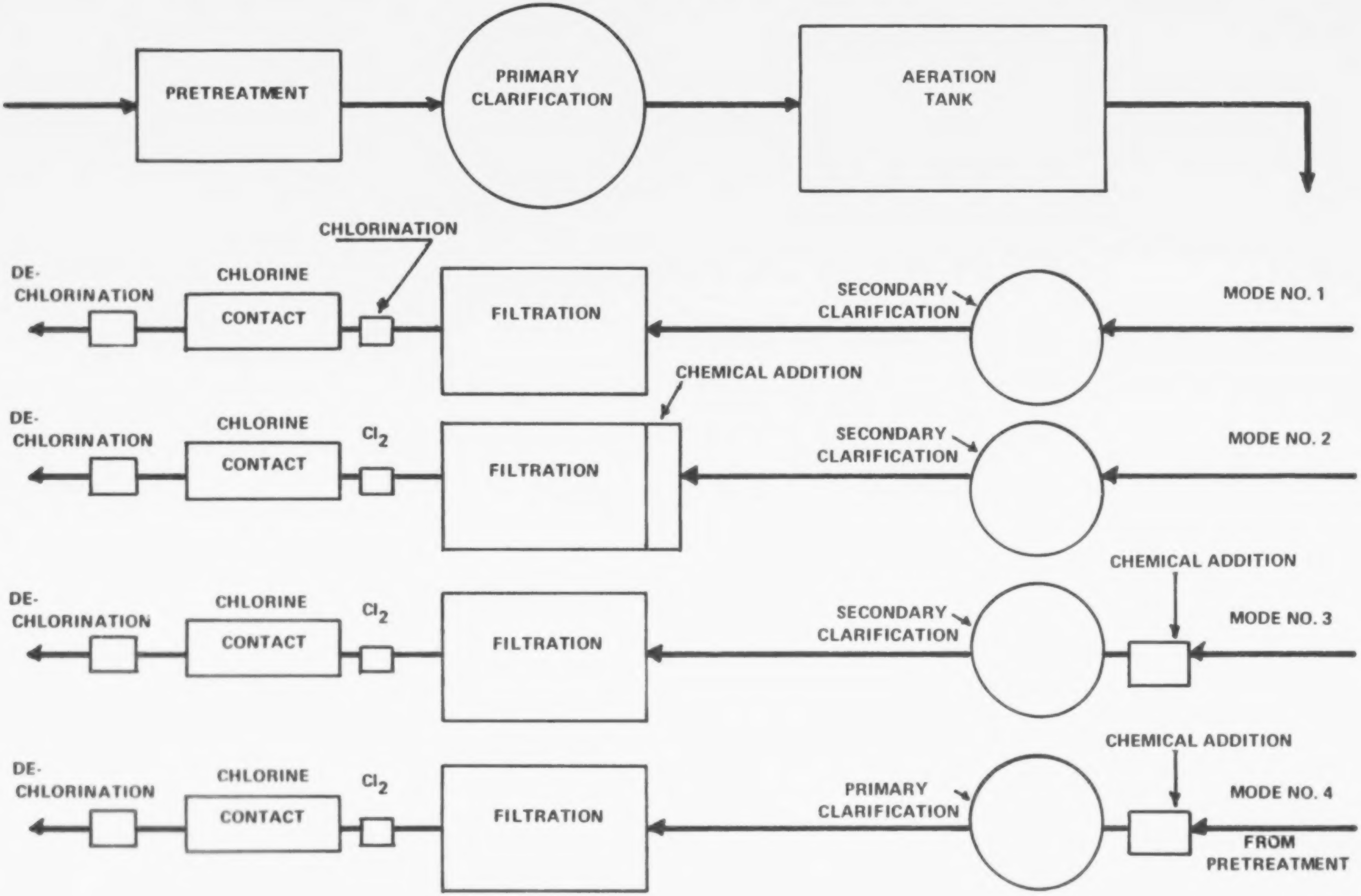

PRETREATMENT
PRIMARY CLARIFICATION
AERATION TANK
CHLORINATION
DE-CHLORINATION
CHLORINE CONTACT
FILTRATION
SECONDARY CLARIFICATION
MODE NO. 1
CHEMICAL ADDITION
DE-CHLORINATION
CHLORINE CONTACT
Cl2
FILTRATION
SECONDARY CLARIFICATION
MODE NO. 2
CHEMICAL ADDITION
DE-CHLORINATION
CHLORINE CONTACT
Cl2
FILTRATION
SECONDARY CLARIFICATION
MODE NO. 3
CHEMICAL ADDITION
DE-CHLORINATION
CHLORINE CONTACT
Cl2
FILTRATION
PRIMARY CLARIFICATION
MODE NO. 4
FROM PRETREATMENT

Fig. 3.19 Four possible modes of using filters to remove solids

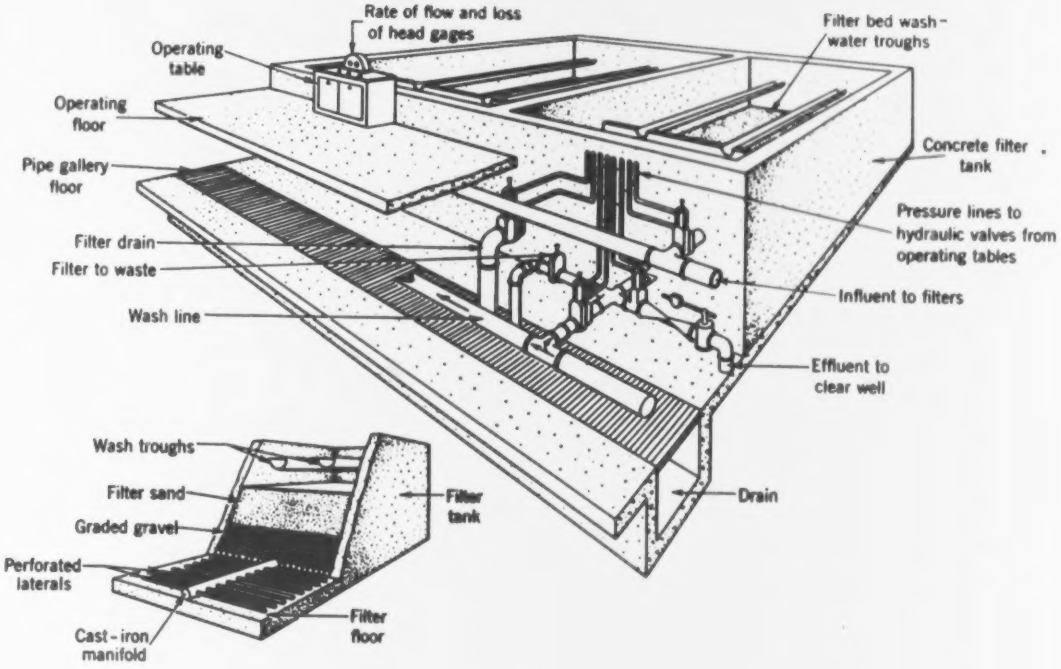
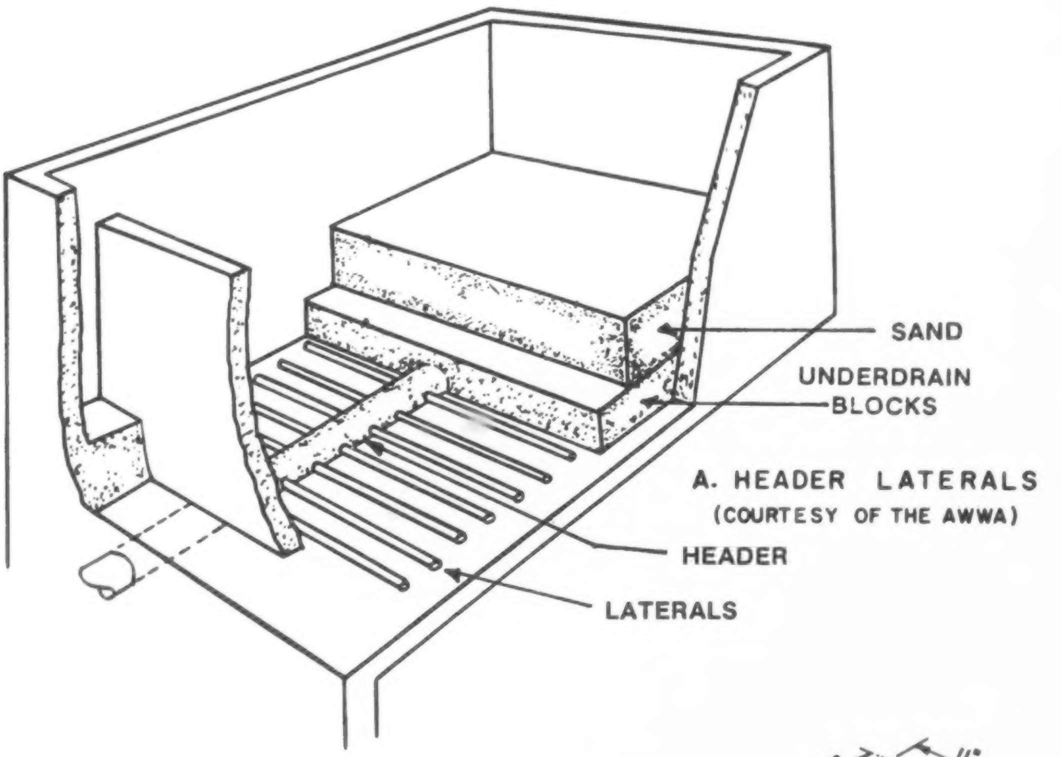
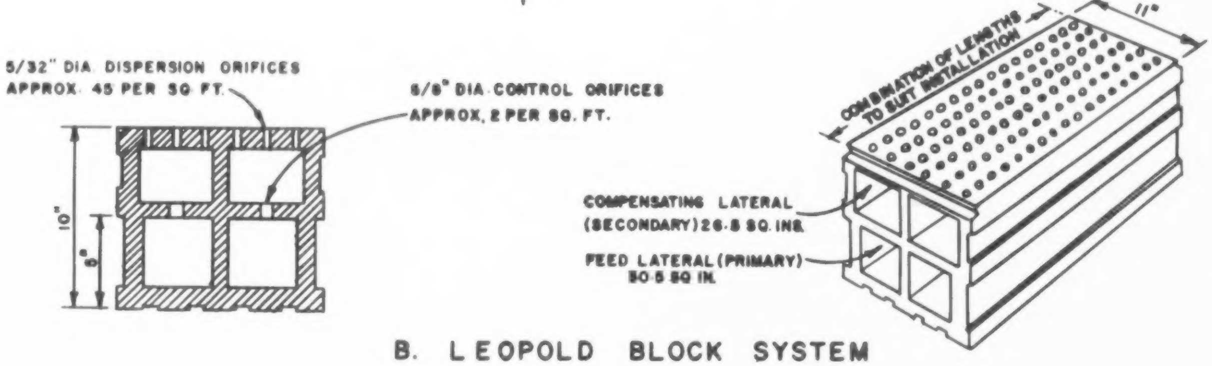

Rate of flow and loss of head gages
Operating table
Operating floor
Pipe gallery floor
Filter drain
Filter to waste
Wash line
Filter bed wash-water troughs
Concrete filter tank
Pressure lines to hydraulic valves from operating tables
Influent to filters
Effluent to clear well
Drain
Wash troughs
Filter sand
Graded gravel
Perforated laterals
Cast-iron manifold
Filter tank
Filter floor

Fig. 3.20 Typical rapid sand filter

(From *WATER SUPPLY AND TREATMENT* by C.P. Hoover, permission of National Lime Association)


SAND
UNDERDRAIN BLOCKS
HEADER
LATERALS

A. HEADER LATERALS
(COURTESY OF THE AWWA)


5/32" DIA. DISPERSION ORIFICES
APPROX. 45 PER SQ. FT.
5/8" DIA. CONTROL ORIFICES
APPROX. 2 PER SQ. FT.
10"
6"
COMBINATION OF LENGTHS TO SUIT INSTALLATION
11"
COMPENSATING LATERAL (SECONDARY) 26.5 SQ. INS.
FEED LATERAL (PRIMARY) 50.5 SQ. IN.

B. LEOPOLD BLOCK SYSTEM

(Courtesy F. B. Leopold Co.)

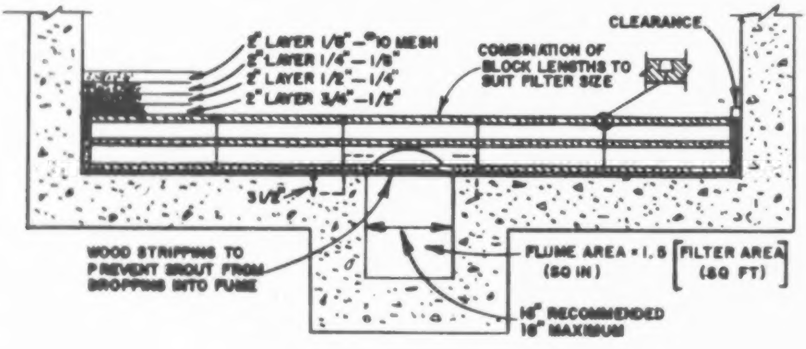

2" LAYER 1/8"—#10 MESH
2" LAYER 1/4"—1/8"
2" LAYER 1/2"—1/4"
2" LAYER 3/4"—1/2"
COMBINATION OF BLOCK LENGTHS TO SUIT FILTER SIZE
CLEARANCE
3 1/2"
WOOD STRIPPING TO PREVENT GROUT FROM DROPPING INTO FLUME
FLUME AREA = 1.5 [FILTER AREA (SQ FT)] (SQ IN)
15" RECOMMENDED
18" MAXIMUM

Fig. 3.21 Underdrains

(Source: *EPA PROCESS DESIGN MANUAL FOR SUSPENDED SOLIDS REMOVAL*)

The air scour system injects air into the bottom of the bed. This agitates the entire bed, yet requires no additional washwater. Care must be taken to prevent air and water flowing at the same time, or the media will be washed out and lost.

3.334 Washwater Troughs

During backwashing, the accumulated solids strained out by the filter media are carried out of the filter bed via the backwash water troughs. The troughs must be level to uniformly collect and withdraw the backwash water. This will help prevent dead spots (short-circuiting) during the backwash operation.

A smooth trough surface, such as fiberglass, will reduce routine cleaning; however, fiberglass troughs may be damaged more easily by the weight of the backwash water than steel or concrete troughs. Filter troughs, particularly fiberglass, must be well anchored to assure that they will not warp or attempt to float during backwashing. They also must be designed to withstand the weight of water if filled when there is no water over the bed.

3.335 Backwash Water Drain

In a wastewater treatment plant, the filter drain allows the backwash water to leave the filter and return to the plant headworks for reprocessing. This drain must be opened before the backwash water flow begins, but not before the water is filtered down below the level of the backwash trough. If the drain opens while the filter is still full of applied water, the water above the troughs will needlessly be recycled back through the plant.

The drain should be closed completely before the inlet valve is opened or applied water again will be wasted.

3.336 Backwash Water Supply

The backwash water is usually water that has gone through the complete treatment process and is of the best quality available. If non-filtered water is supplied to the backwash system, clogging of the underdrain system may occur.

Filter backwashes require large volumes of water over a short period of time; therefore, small- to medium-size plants need a washwater storage reservoir. Water from the chlorine contact tank commonly is used.

Large filters are often split in half to reduce the size of pumps and piping required for backwashing. This also can reduce the water storage requirements because a pause between washing the two halves will provide time to refill the storage reservoir.

Sectional filters (Figure 3.22), designed to backwash one small section at a time, do not require a large backwash water storage supply. These filters use pumped water as it is being filtered through other sections.

3.337 Backwash Water Rate Control

The backwash water may be supplied through pumps or by gravity from a storage tank. Both methods require careful control of the flow rate.

Backwash water supplied through pumps will maintain a more constant flow over the entire wash cycle than washwater from gravity storage. Water supplied from storage tanks may require adjustment of the rate-control valve to maintain constant flows as the storage tank level drops, due to a decrease in the available pressure head on the backwash water.

3.338 Used Backwash Water Holding Tank

The filter backwash water contains solids concentrated from many gallons of applied water. Because of the high solids concentration, this water must be retreated in the treatment process. Since the backwash flow rates are very high, they must be dampened through a holding tank to avoid hydraulic overloads on the treatment plant. If these high flows are returned directly to the headworks in all except the very large plants a hydraulic overload will occur which will upset the treatment process and flow pacing system. A filter system designed to backwash like the sectional filter may avoid the need for a used backwash water holding tank. A holding tank is generally provided to prevent plant overloads. The tank is filled during the backwash operation and slowly emptied into the plant headworks between washings. Some improvement in primary settlement may be noted because of this recycled water.

3.339 Effluent Rate-Control Valve

A valve automatically controls the filtered water flow leaving the bed. The effluent rate-control valve is designed to maintain a constant water level in the filter. When operating a clean filter, this valve will be closed down restricting the flow. As the head loss through the media increases, this valve must open more to maintain a constant flow. This valve must be closed during filter backwash to prevent backwash water from mixing with previously filtered water.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3E What kind of material is used for filter media?

3.3F What can happen if the filter media is not thoroughly cleaned during each backwashing?

3.3G Why should the backwash water be of the best quality available?

3.3H What is the purpose of a used backwash water holding tank?

3.34 Filter System Instrumentation

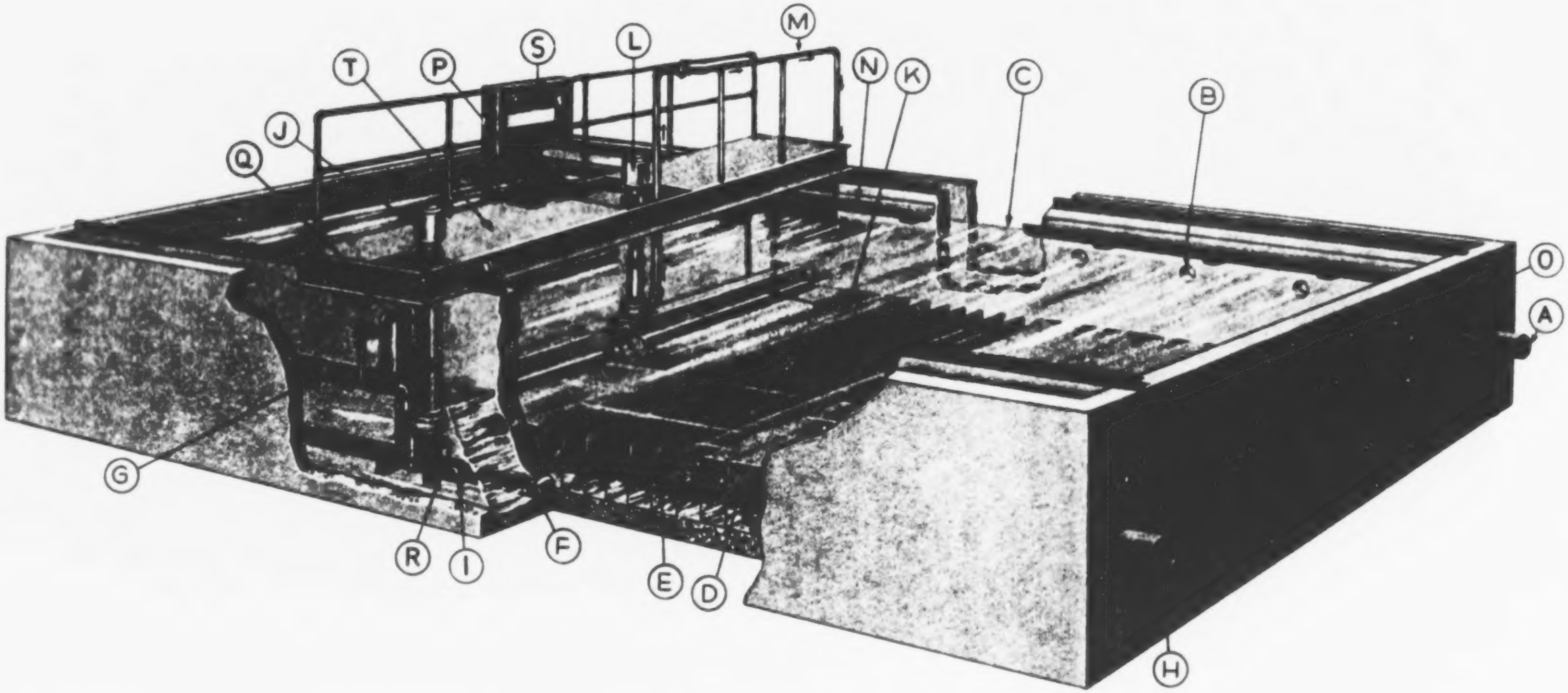
Instrumentation is essential for all but the small package plant installations. Instrumentation associated with filtering is used to monitor the plant performance, to operate the plant in the absence of the operator and to trigger an alarm if abnormal conditions develop. The system may be simple or very complex and, depending on the facilities, each has its place.

Instrumentation, just as all equipment, is only as useful as allowed by the quality of maintenance. Stated another way, if there are intermittent errors in a flow-meter signal and they are not corrected, then the operator cannot trust any of the readings and must disregard all of them. The usefulness of the instrument is then very limited.

Comments regarding instrumentation in the following sections are applicable to plants of all sizes.

3.340 Head Loss

Head loss is one of the most important control guidelines in the operation of the rapid-sand filter. Each filter or filter half requires a head loss indicator, preferably one with a read-out chart. This will indicate the present condition of the bed, its ability to remove solids, and the effectiveness of the backwash operation.



A. Influent line.
B. Influent ports.
C. Influent channel.
D. Compartmented filter bed.
E. Sectionalized under-drain.
F. Effluent and backwash ports.
G. Effluent channel.
H. Effluent discharge line.
I. Backwash valve.
J. Backwash pump assembly.
K. Washwater hood.
L. Washwater pump assembly.
M. Washwater discharge pipe.
N. Washwater trough.
O. Washwater discharge.
P. Mechanism drive motor.
Q. Backwash support retaining springs.
R. Pressure control springs.
S. Control instrumentation.
T. Traveling backwash mechanism.

Fig. 3.22 Sectional filter

(Permission of Environmental Elements Corporation)

Head loss is determined by measuring the water pressure above and below the filter media (see Figure 3.16, page 138). With the filter out of service, the pressure will be the same (zero difference).

When water flows through the bed, the pressure below the media will be less than the pressure above the media (when the pressure levels are measured or read at the same elevation). Measured in feet (or meters) of water, the difference becomes the head loss.

As the media bed becomes filled with solids, the head loss becomes greater. There is a point at which little or no water can pass through the filter. The operator wants the head loss to always be less than at that point; therefore, the filter backwash control point must be less than the maximum design head loss.

A typical set point to start backwash is at 7.0 feet (2.0 m) of head loss. If a filter is operating with a 6.0-foot (1.8 m) head loss, the operator knows the filter will need washing soon. If after washing the head loss is 4.0 feet (1.2 m), this indicates a very poor washing or it may indicate a malfunctioning instrument. After a proper washing, the head loss should be less than 0.5 feet (0.15 m) at start-up. The head loss will then slowly increase to the point where backwashing is required again.

3.341 Filter Flow-Rate and Totalizer

Each filter or filter half requires a flow indicator and totalizer on the filtered water line. This is needed to determine proper filtering rates (gal/min/sq ft or liters/sec/sq meter). Also, with the total volume filtered and the volume of backwash water used, the percent of production (filtered) water used for backwashing can be calculated. This is important because excessive wash water usage is costly and must be controlled. The backwash water should average 5 to 10 percent of total water production.

3.342 Applied Turbidity

A continuous-reading turbidimeter with read-out chart on the applied water is useful in monitoring the performance of the secondary settling tanks. This read-out will alert the operator to pending problems if the turbidity suddenly increases. With experience, chemical dosages can be adjusted as turbidity changes.

3.343 Effluent Turbidity

A continuous reading of turbidity with a chart on the filter effluent will monitor the filter performance. A sudden increase may indicate a filter breakthrough (cracked bed) and may be used or instrumented to set off alarms if specified limits are exceeded. One turbidimeter unit, with proper valving, may be used to monitor more than one filter.

3.344 Indicator Lights

Indicator lights are beneficial to operators in keeping track of the filter system. Lights can easily indicate which filter is in service, out of service, or backwashing. They can indicate if filter pumps, wash water pumps or air blowers are running, out of service or on standby and ready to run. Indicator lights can be used with the alarm system to show abnormal conditions.

3.345 Alarms

Alarms needed to alert the operator should include high applied water level, high turbidity and pump malfunctions. Backwash water supply and holding tanks both need high water level alarms.

All alarms should be tested for proper functioning at least every 60 days.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3I How is the head loss through the filter media determined?

3.3J How often should filter system alarms be tested for proper operation?

3.35 Operation of Gravity Filters

3.350 Pre-Start Checklist

Before starting up any major system, such as gravity filters, a thorough check of each component must be made to prevent damage to the equipment and/or injury to personnel. The following items should be included in your checklist for starting filtering systems.

1. Be sure all construction debris has been removed. Wood scraps, concrete chips, nails and other trash can damage equipment such as pumps and valve seats. Trash dropped into the filter media will work its way to the bottom, thus reducing the effective area of the filter.
2. Inspect the electrical installation for completeness. Check safety lockouts, safety covers and equipment overload protections.
3. Check motors and drives for proper alignment, for proper safety guards, and for free rotation.
4. Examine motors, drive units and bearings for proper lubrication.
5. Check motors for proper rotation. (A three-phase motor may run in either direction.)
6. Inspect pumps and motors for excessive vibration.
7. Fill tanks and piping and look for leaks.
8. Open and close valves manually and run each valve through a complete cycle to check limit setting.
9. Put the automatic controls through a "dry run."
10. Inspect the total system for safety hazards.
11. Backwash the media several times. Skim the fines from the surface between each washing prior to placing filter into service.

3.351 Normal Operation

Since most wastewater gravity filters are deep-bed, downflow, rapid-sand type filters, this section will present information based on them. Nevertheless, most of the information can be applied to other filter designs with some possible modifications.

FILTERING

The applied water enters at the top of the filter bed through an inlet valve and is distributed over the entire filter surface. The water passes evenly down through the media and leaves the solids behind. Filtered water then travels out the bottom of the filter and into the underdrain collection system which is designed to uniformly collect the flow. Once inside the underdrain collection system, the water passes through a flow meter and rate-control valve. The rate-control valve maintains the desired flow through the filter and prevents backwash water from entering the filtered water during backwashing. Successful filter operation depends on effective backwashing of the filter media.

BACKWASHING

As suspended solids are removed from water, the filter media becomes clogged. This is indicated by the head loss reading (Figure 3.16, page 138). Through operating experience, the maximum head loss before backwashing will be determined. The filter should be backwashed after the solids capacity of the media has been met, but before solids break through into the effluent.

By maintaining complete records, the operator can monitor the filter efficiency and determine if the backwashings are adequate.

Backwashing a filter manually, although sometimes necessary, is very time-consuming; moreover, manual backwashings are inconsistent. Automatic backwashing, on the other hand, can be a simple procedure which requires a minimum of operator time.

To maintain smooth operations, the automatic backwash cycle should be initiated by the operator. This mode of operation permits the operator to backwash at a convenient time thereby allowing time for keeping records current and completing the necessary maintenance duties. Automatically starting backwashes, although workable in a large system, can be very inconvenient to the operation of a small system.

At the start of the backwash cycle, the rate-control valve must be opened slowly to a low-rate of backwash. This prevents damaging the underdrain system or disturbing the rock and gravel layers of the bed. This damage can occur when an empty bed has high backwash water flows suddenly injected into it or if trapped air in the piping and underdrain system is violently forced into the bed. After the air has been purged and the water level is up to the washwater troughs, the bed can no longer be damaged by high backwash rates.

Some plants use an air scouring system to clean the filter media. The air scour system injects air into the bottom of the media bed. This agitates the entire bed, yet requires no additional washwater. Care must be taken to prevent air and water flowing at the same time, or the media will be washed out and lost.

To prevent the loss of filter media into the backwash troughs:

1. Draw the water-level in the filter down to within a few inches over the top of the filter media,
2. Pause a moment after air washing before starting the water wash,
3. Wash with a low water-flow rate until the trapped air has escaped the filter media, and
4. Never backwash a filter with water containing large quantities of air.

The media becomes intermixed during the high agitation of air scrubbing or high-rate backwashing. With proper control, however, the media will automatically regrade due to the difference in specific gravities of the particles.

By design, the filter media is prevented from escaping into the underdrain system; nevertheless, operational care must be taken to prevent damaging the underdrains while backwashing or the filter media will be lost into the underdrain collection system.

Uniform water flow through the filter bed is important to prevent the breakthrough of solids in the effluent due to localized high velocities. Also, high velocities will cause the media to be disturbed and relocated during backwash if the backwash flow is not uniform throughout the bed.

The following situations indicate a disturbed or damaged filter underdrain:

1. Consistently poor quality effluent (high suspended solids levels) while there is little buildup of the filter head loss.
2. Boiling areas and very quiet ("dead") areas of the filter media during backwashing. This is most noticeable during high wash rates in a nearly clean filter.
3. Filter media in the effluent.

Improper control of the system during backwashing is generally the cause of damaged filter bottoms, providing they were properly installed. Damage to the filter bottom could result if:

1. The maximum backwash rate is allowed to enter into an empty filter, or
2. A large volume of air preceded the maximum backwash rate causing a *WATER HAMMER*.[9]

The only way to correct a damaged filter bottom is to remove the media and rebuild the bed. A bed with the media displaced to a minor extent may be corrected by extended and properly controlled backwashing. This will regrade the media.

After backwashing, the filter normally has water up to the sides of the troughs. To fill the remaining portion of the filter, open the inlet valve. If the filter has been drained for maintenance, fill the filter, as if you were starting to backwash, up to the top of the sides of the troughs. Now you can fill the filter using the inlet valve. Be sure to waste some of the filtered water at the start until completely filtered and clear water is leaving the filter. An empty filter should not be filled through the inlet valve because the water falling onto the media will disturb the bed and result in uneven filtering. Also, filling the backwash troughs with water in an empty filter will place an unnecessary load (weight of water) on the troughs.

After the filter media is clean, the backwash water flow is slowly reduced. This permits the media to regrade itself through gravity settling. The heavier particles (gravel, garnet, sand) will settle to the bottom first and as the uplift velocities reduce, the lighter particles (anthracite coal) will settle, thereby regrading the filter bed back to its original placement. This regrading must occur at the end of each backwash cycle.

When the used backwash water holding tank is empty, the tank should be inspected. A check observation of the solids settled on the bottom of the empty holding tank will alert the operator to any loss of filter media due to improper backwash procedures, such as excessively high flow rate or short-circuiting.

By analyzing the records and observing the complete wash cycle, the operator can determine if the backwashing sequence is adequate. If highly turbid water is still in the bed at the end of the cycle, experiment with one or all of the following:

1. Adjust the media scouring time,
2. Adjust the low wash rate,
3. Adjust the high wash rate,
4. Adjust the time of regrading the media, and/or
5. Backwash more frequently by beginning to wash at a lower head loss.

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[9] *Water Hammer. The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3K Why should a pre-start check be conducted before starting filtering systems?

3.3L What is the purpose of the rate-control valve?

3.3M When should a filter be backwashed?

3.352 Abnormal Operations

Following is a list of conditions that are not normally found in the day-to-day operation of filtration systems; however, these conditions could occur at almost any time. Recommendations are added to aid you in adjusting to the situation.

1. High solids in the applied water due to bulking sludge, rising sludge, or solids washout in the secondary clarifier.
   a. Run *JAR TESTS*[10] and adjust chemical dosage as needed.
   b. Place more filters in service to prevent breakthrough.
   c. Prepare to backwash more frequently.
2. Low suspended solids in applied water; however, solids pass through filter.
   a. Run jar tests and adjust chemical dosage as needed. Test a combination of chemicals and polyelectrolytes.
   b. Place more filters in service to reduce velocity through the media.
   c. Backwash filter and pre-coat clean filter with *FILTER AID.*[11]
3. Loss of filter aid chemical feed.
   a. Place more filters in service to reduce velocity through media.
   b. Backwash more frequently.
   c. Pre-coat clean filters by hand feeding chemicals into them when first placed into service.
4. High wet weather peak flows.
   a. Place more filters in service.
   b. Run jar tests and adjust chemical dosage as needed.
   c. Prepare for peak daily flows by backwashing early.
5. Low applied water flows.
   a. Reduce number of filters in service. Run one-half of a filter at a time.
   b. Prepare to take extra filters out of service and backwash when flow or head loss increases, thereby preventing breakthrough.
6. High color loading.
   a. Run jar tests and adjust chemical dosage as needed.
   b. Add chlorine to applied water.
   c. Usually color cannot be removed with filtration; consequently the problem must be corrected at the source.
7. High temperature.
   a. Run jar tests and adjust chemical dosage as needed.
   b. Prepare for *AIR BINDING*[12] of filters because water will release gases more readily at higher temperatures.
   c. Place more filters in service to reduce head loss through the media.
   d. Increase backwash water flow rates to obtain the same bed expansion as used when backwashing with colder water.
8. Low water temperature.
   a. Run jar tests and adjust chemical dosage as needed.
   b. Prepare for air binding of filters as cold water will carry more gases to the filters. Backwash more frequently if air binding occurs.
   c. Place more filters in service to reduce head loss through filter media.
   d. Reduced backwash water flow rates to obtain the same bed expansion as used when backwashing with warmer water.
9. Air binding.
   a. Backwash at a lower head loss.
   b. Place more filters on line to reduce head loss through media.
   c. Take filter out of service and allow air to escape to the atmosphere. This will reduce head loss; however, if placed back into service without backwashing, solids will likely be drawn through the media and into the effluent. These solids may or may not cause a problem.
10. Negative pressure in filter.
   a. Reduce flow through the filter by adding additional units.
   b. Backwash at a lower head loss.
   c. Skim surface of media (about one-half inch or 1.3 cm) to remove fines.
   d. Prevent filter from running at a low filtration rate. This builds a mat on the media surface and then sharply increases the head loss if a higher rate of water flows through the filter.
   e. A negative pressure within the filter will cause a false reading from the differential pressure sensor.

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[10] *Jar Tests. A laboratory procedure that simulates coagulation/flocculation with differing chemical doses. The purpose of the procedure is to* ESTIMATE *the minimum coagulant dose required to achieve certain water quality goals. Samples of water to be treated are placed in six jars. Various amounts of chemicals are added to each jar, stirred and the settling of the solids is observed. The lowest dose of chemicals that provides satisfactory settling is the dose used to treat the water.*

[11] *Filter Aid. A chemical (usually a polymer) added to water to help remove fine colloidal suspended solids.*

[12] *Air Binding. The clogging of a filter, pipe or pump due to the presence of air released from water.*

11. High BOD and COD.
    a. Handle same as high suspended solids.
    b. Chlorinate applied water.
12. High coliform group bacteria levels.
    a. Chlorinate applied water to increase contact time.
    b. Place additional units in service to increase contact time.
    c. Run jar tests and adjust chemical dosage as needed to reduce suspended solids.
13. Chlorine in applied water.
    a. Discontinue adding polyelectrolytes as chlorine will interfere with them.
    b. Run jar tests and adjust chemical dosage as needed.
14. pH change in applied water.
    a. Run jar tests and adjust chemical dosage as needed.
    b. Change type of filter aid if necessary.
15. High grease and oil in applied water.
    a. If in solution, they will pass through media.
    b. If not in solution, they will be trapped in the bed, thus requiring extra hosedown during each backwash.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3N List at least five of the various types of abnormal operating conditions that could occur while operating a filtration system.

3.3O How would you adjust to a situation in which you were treating a high solids content in the water applied to a filter?

3.353 Operational Safety

The development of an operational strategy for the filtration of wastewater will aid in dealing with situations such as sudden changes in applied water, in training new operators or in planning for the future. Following are points to consider when developing or reviewing your plans.

1. Maintain the filtering rates within the design limits. Add units or remove them from service as needed. Very low filtering rates will produce matting on the surface. This matting will cause breakthroughs if the flows are increased sharply. Excessively high rates will pull the solids through the filter and into the effluent.
2. Each backwash must be a complete cleaning of the media or solids will build up and form mudballs, or cause the media to crack.
3. To remove mudballs, first backwash thoroughly. Then super chlorinate manually and draw the chlorinated water into the filter media. Allow this chlorinated water to stand for 24 or 48 hours to soak the mudballs and finally backwash thoroughly again.
4. Run jar tests to maintain optimum chemical dosages. As the applied water quality changes (solids, alkalinity, temperature), the filter aid requirements will change. The operator must be aware of the changes and the effectiveness of the chemicals applied.
5. With complete backwashing, a high quality effluent can be maintained without filtering to waste before placing the filter back into service.
6. If the effluent turbidity reaches 3 to 4 *TURBIDITY UNITS,*[13] a change should be made to correct the problem. Either adjust chemical dosage, adjust flow rate or backwash the filter.
7. Filter walls that are constructed with a smooth surface (sacked) or painted with a good sealant are easy to keep clean. A rough surface provides an excellent area for algae and slimes to grow.
8. Controls and instrumentation must be protected from the elements. Cabinets that are opened to adjust instruments must be out of the rain, dust and extreme heat.
9. Air used to operate instruments or transmit signals must be *CLEANED AND DRIED* to prevent damaging the equipment.
10. Every three to four months, measure and record the freeboard to the filter media surface (Figure 3.23). A small amount of media loss is normal, but an excessive amount (2 to 3 inches or 5 to 7 centimeters) indicates operational problems.
11. After the filters have been in service for some time, obtain a profile of the media to determine if it is being displaced. A plug sample will show if the media are being regraded after each backwash.
12. When landscaping around uncovered filters, keep trees and shrubs that will drop leaves into the bed away from the filter because leaves are very difficult to backwash out of the media.
13. Never throw trash such as cigarette butts into the filter media. Trash may not backwash out and instead may work its way into the media.
14. Occasionally chlorinate ahead of the filters to control algae and slime growths on the walls and within the media. There will be a short period of discolored effluent after the initial application, but the water will turn clear in a short while.
15. Calculate the unit cost to treat wastewater. Apply this cost to the volume of water used per backwash. Inform all operators of this because it may easily cost in excess of $100 per filter wash.
16. Always fill an empty filter bed through the backwash system to prevent disturbing the media surface. If an empty filter is filled through the influent valve, water will flow into the washwater troughs, over the top edges and onto the top of the media. The force of this falling water will disturb the media.
17. Allow dry filter media to soak several hours before backwashing. Dry media will tend to float out with the backwash water.

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[13] *Turbidity Units. Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water, they are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.*

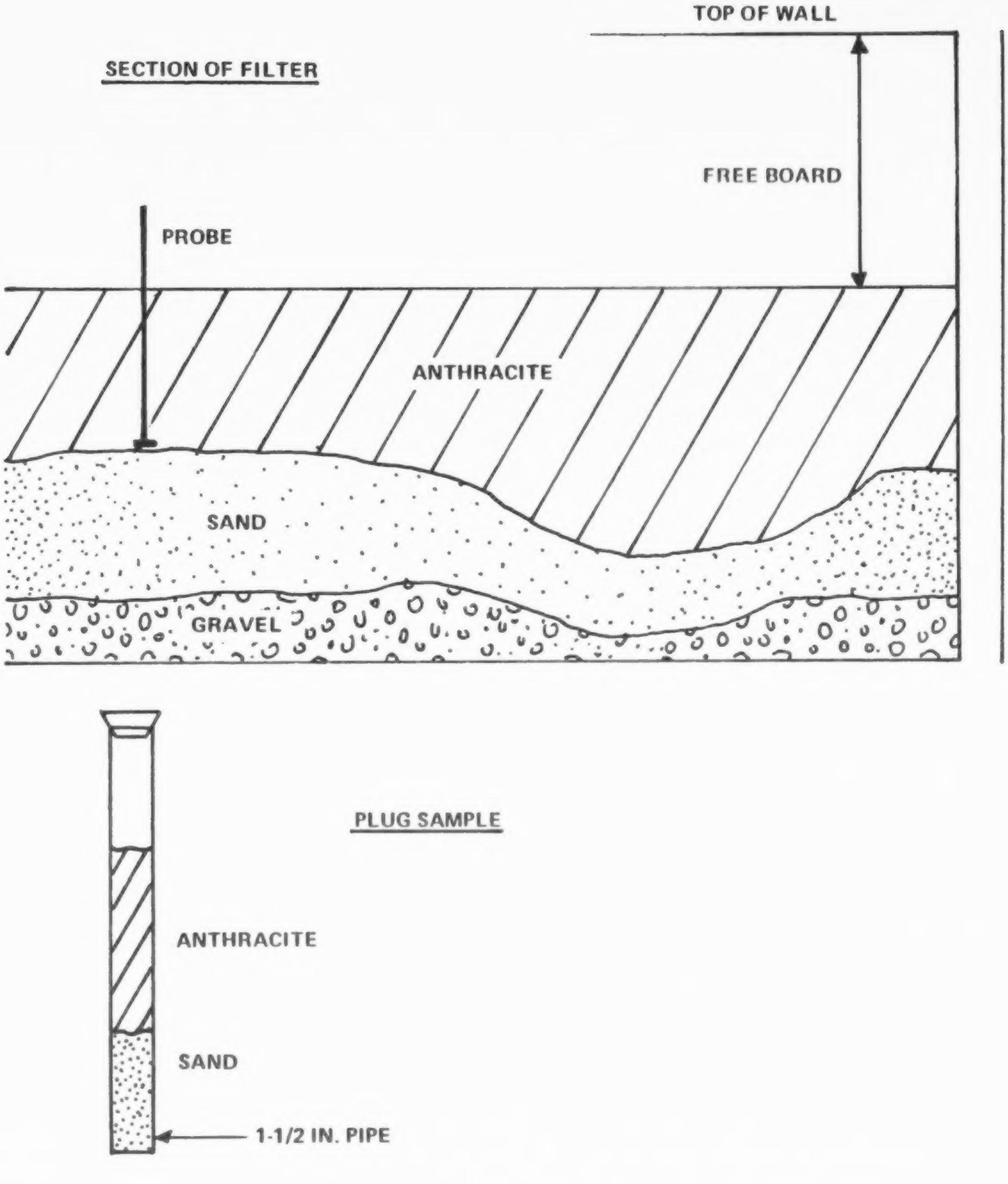

SECTION OF FILTER
TOP OF WALL
FREE BOARD
PROBE
ANTHRACITE
SAND
GRAVEL
PLUG SAMPLE
ANTHRACITE
SAND
1-1/2 IN. PIPE

Fig. 3.23 Section of filter and plug sample

18. Maintain a log (Figure 3.24) of the filtering operation which includes the following:
    a. Time filter was placed into service and total hours run between washings,
    b. Volume of water processed between washings,
    c. Applied water rate at start and end of filter run,
    d. Head loss at start and end of filter run,
    e. Applied suspended solids and BOD,
    f. Effluent suspended solids and BOD,
    g. Percent removal of suspended solids and BOD,
    h. Chemicals added as filter aids, mg/*L*,
    i. Chlorine added to applied water, mg/*L*,
    j. Remarks of special observations and maintenance,
    k. Backwash water flow rates and duration,
    l. Surface wash flow rate and duration, and
    m. Influent and effluent turbidity.

3.354 Shutdown of a Gravity Filter

If the filter is to be out of service more than a week, it should be dewatered and air dried. This will help control slime and algae growth on the walls, troughs and within the media. Dried algae can be hosed from the walls prior to backwashing and returning to service.

To remove a filter from service, switch controls to the manual mode of operation and then:

1. Close the influent valve,
2. Filter all the water possible through the rate-control valve, and
3. Open the drain valve.

Hose down and backwash the filter before returning it to service.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3P How would you determine if media are being lost from a filter?

3.3Q Why should trees and shrubs be kept away from uncovered filters?

3.36 Troubleshooting

PROBLEM: HIGH TURBIDITY AND SUSPENDED SOLIDS IN THE EFFLUENT.

1. Check for excessive head loss. Breakthrough will occur at a high head loss.
2. Look for fluctuating flows. Widely varying flows will cause breakthrough.
3. Determine filter aid dosages.
4. Examine backwash cycle for complete wash.
5. Inspect for damaged bed due to backwashing.

PROBLEM: RAPID BUILDUP OF HEAD LOSS.

1. Check applied water suspended solids.
2. Check filter aid dosage.
3. Determine applied water flow rate.
4. Check backwash cycle for complete wash.
5. Inspect head loss differential pressure sensor for air in one side. This will give a false reading.

PROBLEM: INSIGNIFICANT BUILDUP OF HEAD LOSS.

1. Check applied water suspended solids.
2. Check applied water flow rate.
3. Determine filter aid dosages.
4. Check head loss differential pressure sensor for air in one side. This will give a false reading.
5. Examine filter effluent for suspended solids going out (filter breakthrough).
6. Inspect for damaged bed due to backwashing.
7. Backwash and check for complete cycle.

PROBLEM: RAPID LOSS OF FILTER MEDIA.

1. Look for washout during backwash cycle.
2. Examine for media in effluent indicating a damaged filter underdrain.
3. Check for excessive scouring during backwash cycle time. Excessive scouring will grind the media into fines.

PROBLEM: HIGH HEAD LOSS THROUGH CLEANED FILTER.

1. Inspect differential pressure sensor for air in one side.
2. Check for incomplete backwash cycle.
3. Look for mudballs in filter media. Take a plug sample. (Fig. 3.23, page 150)

PROBLEM: FLOW INDICATED WHEN EFFLUENT VALVE IS CLOSED.

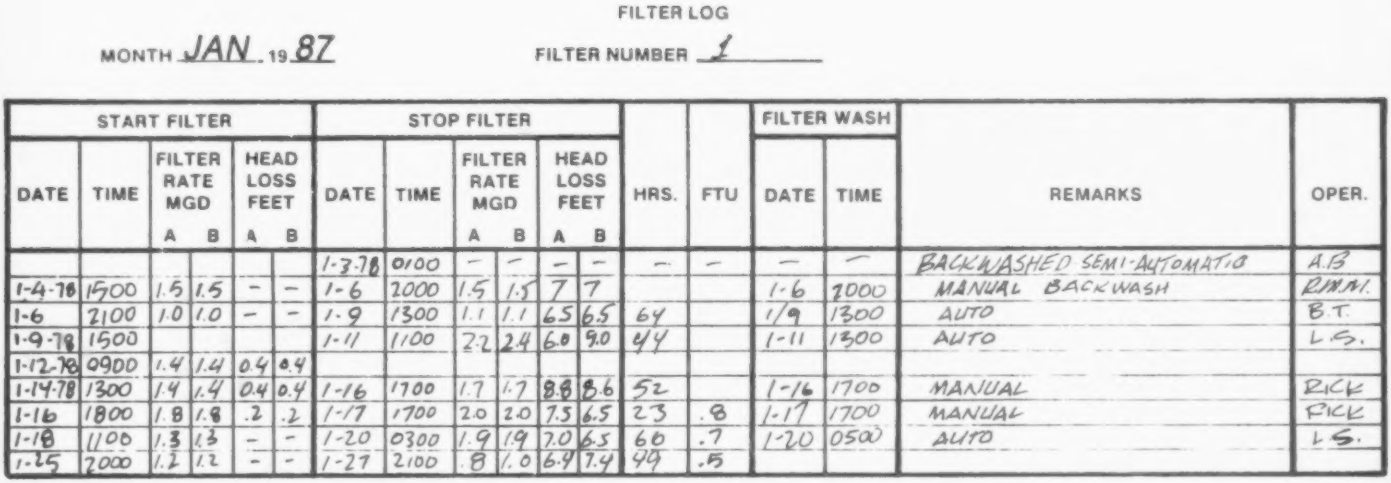
1. Inspect differential pressure sensor for air in one side.
2. Check instrumentation loop for calibration.
3. Examine valve for proper position.

PROBLEM: BACKWASH STOPS BEFORE COMPLETING CYCLE.

1. Look for sticking valve.
2. Inspect for electrical relay hang-up.
3. Check for timer out of sequence.
4. Examine backwash water supply.
5. Inspect electrical control (pump lock-out).

3.37 Safety

Always think safety when working around moving equipment and motors with automatic controls. Filtration systems have electrical, chemical and mechanical safety hazards. Operators are usually well protected from electrical hazards; however, there are times when opening a panel to look for trouble or to adjust a timer may expose you to electrical hazards. Always



FILTER LOG

MONTH JAN 19 87

FILTER NUMBER 1

START FILTER						STOP FILTER								FILTER WASH			
DATE	TIME	FILTER RATE MGD		HEAD LOSS FEET		DATE	TIME	FILTER RATE MGD		HEAD LOSS FEET		HRS.	FTU	DATE	TIME	REMARKS	OPER.
		A	B	A	B			A	B	A	B						
						1-3-78	0100	–	–	–	–	–	–	–	–	BACKWASHED SEMI-AUTOMATIC	A.B
1-4-78	1500	1.5	1.5	–	–	1-6	2000	1.5	1.5	7	7			1-6	2000	MANUAL BACKWASH	R.M.M.
1-6	2100	1.0	1.0	–	–	1-9	1300	1.1	1.1	6.5	6.5	64		1/9	1300	AUTO	B.T.
1-9-78	1500					1-11	1100	2.2	2.4	6.0	9.0	44		1-11	1300	AUTO	L.S.
1-12-78	0900	1.4	1.4	0.4	0.4												
1-14-78	1300	1.4	1.4	0.4	0.4	1-16	1700	1.7	1.7	8.8	8.6	52		1-16	1700	MANUAL	RICK
1-16	1800	1.8	1.8	.2	.2	1-17	1700	2.0	2.0	7.5	6.5	23	.8	1-17	1700	MANUAL	RICK
1-18	1100	1.3	1.3	–	–	1-20	0300	1.9	1.9	7.0	6.5	60	.7	1-20	0500	AUTO	L.S.
1-25	2000	1.2	1.2	–	–	1-27	2100	.8	1.0	6.4	7.4	49	.5				

Fig. 3.24 Log of filter operation

use safety equipment (rubber electrical gloves, voltage test meters, fuse pullers, and lock-out switches) and approved safety procedures when working with electricity.

Chemical hazards include chemical burns and skin irritation from direct contact with chemicals. Also, there is the hazard of slipping and falling caused by chemical spills. Good housekeeping will reduce the safety hazards caused by chemicals.

Mechanical hazards associated with filters are similar to those found throughout the treatment plant. Safety guards must be in place, equipment operated automatically must be identified by warning signs, and work areas should be well lighted.

3.38 Review of Plans and Specifications

While reviewing the plans and specifications of a gravity filtration system, you should consider the items listed in this section.

1. Filters require regular servicing; therefore, provisions must be made to handle the normal flows during periods of servicing. Regular maintenance includes servicing of valves, instruments and filter media.
2. The quality of the water applied to the filters must be considered when a filtering media is specified. A high suspended solids content in the applied water will quickly plug a fine-media filter, thereby requiring frequent backwashing.
3. Install sufficient instrumentation to adequately monitor the process and to determine operating efficiencies. Include instrumentation to measure and record applied flows, backwash flows, head loss, and water quality before and after filtration.
4. Be sure that each step in the automatic system is complete before the following or next step can begin.
5. Provide a means to reset the automatic system if the backwash cycle is interrupted.
6. Keep the automatic backwashing system uncomplicated, especially in small plants. The operator should be on hand at the start of a filter backwash cycle. Housekeeping chores can be performed while keeping an eye on the filter washing process.
7. Install instruments out of the weather and well protected from the weather. Even weather-proof cabinets must be opened during the maintenance and servicing of instruments and equipment.
8. Install the instruments' read-out meters, charts and gages in a convenient and centralized location.
9. Separate and shield instrumentation signals from all high voltage (110 volts and higher) and from other equipment noise that may be picked up by the instruments as a false signal.
10. Provide adequate storage for chemicals. A minimum supply of chemicals must be on hand even while waiting for a full shipment.
11. Provide adequate storage for both the backwash water supply and the used backwash water.
12. When reviewing designs for the future, keep today's flows in mind. Equipment operating below 10 percent capacity may be useless for years.
13. Visit similarly designed plants that are currently in operation and talk to the operators regarding possible design improvements.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 169.

3.3R What are the three main types of safety hazards around filtration systems?

3.3S When reviewing plans and specifications for a filtration system, instrumentation should be available to measure and record what items?

3.3T Where should the instruments' read-out meters, charts and gages be installed?

END OF LESSON 3 OF 4 LESSONS
ON
PHYSICAL-CHEMICAL TREATMENT

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 4 Lessons)

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

13. Why are multi-media filters used?
14. How can a filter bottom be damaged?
15. What is the purpose of instrumentation used with a filter system?
16. How does a rapid-sand filter work?
17. Why should you attempt to maintain filtering rates within the design limits?
18. How would you remove a gravity filter from service?

CHAPTER 3. PHYSICAL-CHEMICAL TREATMENT

By Ross Gudgel

(Lesson 4 of 4 Lessons)

3.4 SOLIDS REMOVAL FROM SECONDARY EFFLUENTS USING INERT-MEDIA PRESSURE FILTERS

3.40 Use of Inert-Media Pressure Filters

Inert-media pressure filters remove suspended solids and turbidity from the secondary effluent after the addition of chemical coagulants such as a polymer and/or alum. The filtration process is used to meet waste discharge requirements for final effluent suspended solids and turbidity limits established by an NPDES permit when these limits cannot be met by secondary treatment processes. Filtration also will have a direct bearing on the disinfection of the final effluent by the removal of more solids from the water to be disinfected. Fewer solids will reduce the amount of chlorine necessary to meet the NPDES permit coliform requirements.

The filter system usually consists of:

1. A holding tank or wet well for secondary effluent storage,
2. Filter feed pumps which pump the secondary effluent from the holding tank to the filters,
3. A chemical coagulant feed pump system which injects the necessary coagulants into the influent line to the filters,
4. Single, dual, or multi-media filters that trap the suspended solids and remove the turbidity,
5. A filter backwash wet well for clean backwash water storage,
6. Filter backwash pumps which pump clean water back through the filter to remove the trapped suspended solids, and
7. A decant tank that provides for holding the spent backwash water to allow the suspended solids to settle while the clarified water is either directly recycled to the filtlers or is returned to the headworks.

Figure 3.25 shows a schematic view of the items outlined above and further discussed in the following sections.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

3.4A What is the purpose of the inert-media pressure filter?

3.4B What chemicals are commonly used with the filtration process and why?

3.4C List the major components of a pressure filter system.

3.41 Pressure Filter Facilities

The following sections describe facilities which are typical for a filter plant with a capacity of 5 MGD. Facilities at larger or smaller plants would be quite similar but might differ significantly in the numbers and sizes of the various components.

3.410 Holding Tank (Wet Well)

Secondary effluent from the treatment plant's secondary sedimentation tanks is conducted through a channel or pipe to a holding tank. The purpose of this tank is to store water and to allow additional settling to the suspended solids before the water is applied to the filters. Most tanks of this type are very similar to secondary clarifiers. They have flights or scrapers to move the settled solids towards a sludge hopper for return to the solids handling facility.

A bypass structure should be provided to permit secondary effluent to bypass the pressure filters during emergency conditions, such as equipment failures or clogged filters. Bypassed flows should go into emergency holding basins or into the chlorine contact tank for final treatment before discharge. An alternate emergency storage procedure would be to divert secondary effluent into the decant tank.

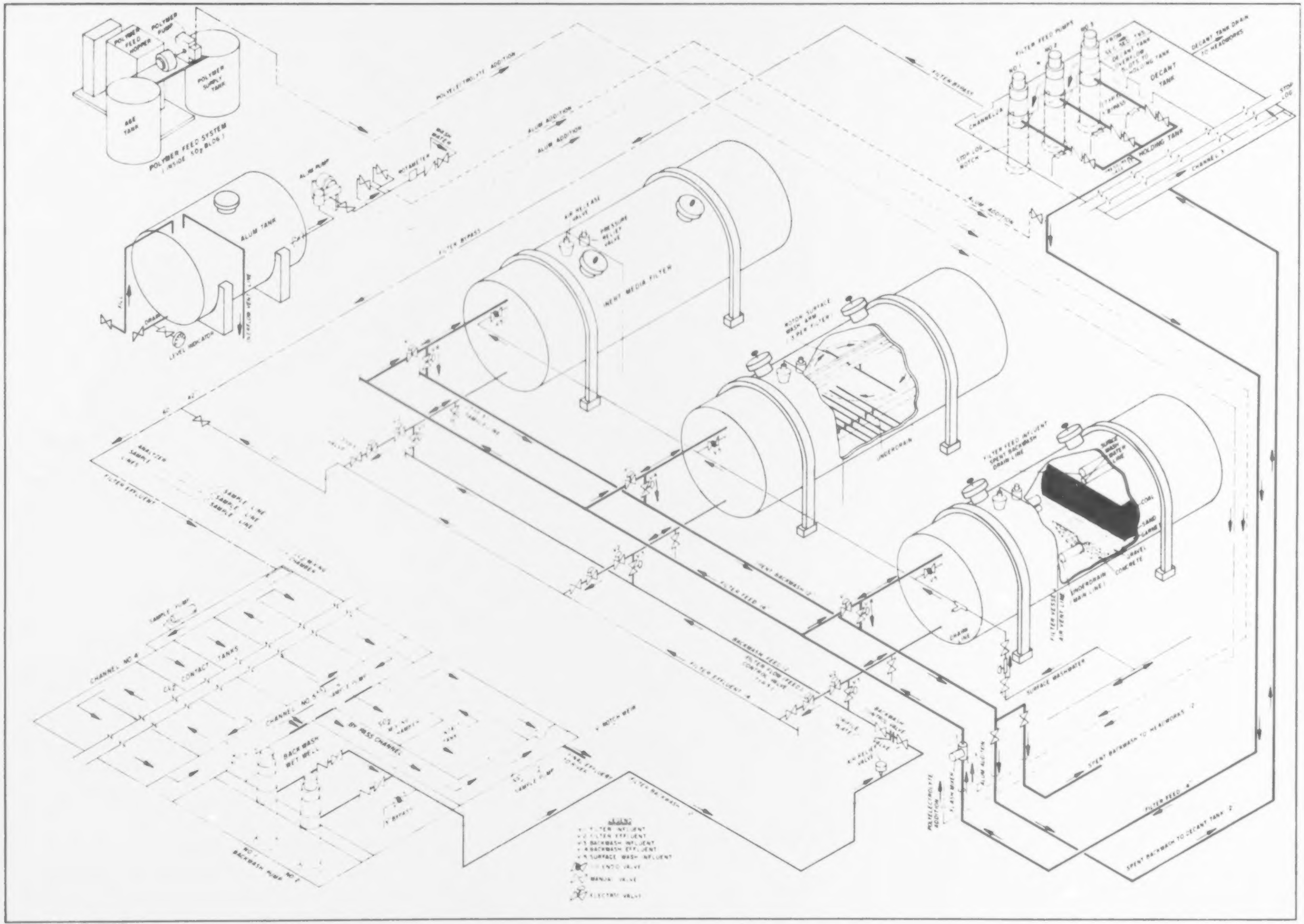

POLYMER FEED HOPPER
POLYMER PUMP
POLYMER SUPPLY TANK
AGE TANK
POLYMER FEED SYSTEM (INSIDE SO_2 BLDG.)
POLYELECTROLYTE ADDITION
ALUM ADDITION
ALUM PUMP
ROTAMETER
WASH WATER
ALUM TANK
FILTER BYPASS
LEVEL INDICATOR
DRAIN
AIR RELEASE VALVE
PRESSURE RELIEF VALVE
INERT MEDIA FILTER
ROTOR SURFACE WASH ARM
UNDERDRAIN
FILTER FEED INFLUENT SPENT BACKWASH DRAIN LINE
SURFACE WASH WATER LINE
COAL
SAND
GARNET
GRAVEL
CONCRETE
UNDERDRAIN MAIN LINE
DRAIN LINE
SURFACE WASHWATER
FILTER FEED PUMPS
NO. 1
NO. 2
NO. 3
CHANNEL 5
STOP LOG NOTCH
DECANT TANK
HOLDING TANK
DECANT TANK DRAIN TO HEADWORKS
STOP LOG
CHANNEL 7
ANALYZER SAMPLE LINES
FILTER EFFLUENT
SAMPLE LINE
SAMPLE LINE
SAMPLE LINE
INERT BACKWASH
FILTER FEED
BACKWASH FEED
FILTER FLOW FEED CONTROL VALVE
FILTER EFFLUENT
SAMPLE PUMP
CHANNEL NO. 6
Cl_2 CONTACT TANKS
CHANNEL NO. 5
BACKWASH WET WELL
BY PASS CHANNEL
V-NOTCH WEIR
NO. 1 BACKWASH PUMP NO. 2
FILTER BACKWASH
BACKWASH CONTROL VALVE
AIR RELEASE VALVE
POLYELECTROLYTE ADDITION
ALUM ADDITION
SPENT BACKWASH TO HEADWORKS
FILTER FEED
SPENT BACKWASH TO DECANT TANK
LEGEND
V-1 FILTER INFLUENT
V-2 FILTER EFFLUENT
V-3 BACKWASH INFLUENT
V-4 BACKWASH EFFLUENT
V-5 SURFACE WASH INFLUENT
SOLENOID VALVE
MANUAL VALVE
ELECTRIC VALVE

Fig. 3.25 Schematic view of pressure filter system

Spent backwash water may also be returned to the decant tank. Both flows receive some settling and the clarified effluent then overflows into the holding tank through weir slots between the two tanks for recycle to the filters. In either method of operation, the flotable materials in the holding tank are collected and discharged to the solids handling section of the plant for disposal. For additional information on clarifier operation and maintenance, see Chapter 5, "Sedimentation and Flotation," Volume I, *OPERATION OF WASTEWATER TREATMENT PLANTS.*

3.411 Filter Feed Pumps (Figure 3.26)

Filter feed pumps lift the secondary effluent from the holding tank and pump it through the filters. Generally they are of the vertical-turbine wet-pit type pump with either a closed or semi-open impeller. The pumps are driven by either fixed-speed, multi-speed (two speed), or variable-speed motors or a combination of these. Each pump should be equipped with a manually adjusted bypass valve to avoid the possibility of the system operating at the shutoff pressure of the pumps. If this happens, the pumps could be damaged because no water would flow through the pumps. Each valve should be adjusted to allow a given bypass flow as recommended by the manufacturer.

The water level in the holding tank may be sensed by a level transmitter. The transmitter provides a signal used for starting and stopping of the pumps and for a set point signal for the controller which controls filter flow.

Starting and stopping of the pumps is controlled by a HAND-OFF-AUTO (HOA) switch for each pump. Another switch is used to select the sequence of automatic starting (lead or lag). Normal automatic start-stop control of the pumps may be by means of current trips using the signal representing the water level in the holding tank. A low-water probe in the holding tank will stop all pumps if the water level drops below a pre-set elevation. For additional information on the operation and maintenance of pumps, see Chapter 15, "Maintenance," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS.*

3.412 Chemical Feed Systems

Various types of chemicals may be added to the filter influent flow to insure coagulation and flocculation of the suspended material. This coagulation and flocculation aids the filtering process by joining many of the finely divided and colloidal suspended solids into a floc mass which is easily trapped on or in the filter media, thus allowing clear water to pass through the filter. Alum and polymers are the most common chemicals used.

A discussion of the reasons for using chemicals and the method of feed is contained in this section.

ALUM (ALUMINUM SULFATE) (Figure 3.27)

Alum is a coagulant which produces a hydrous oxide floc. This floc causes suspended material to stick together by electrostatic or interionic force when contact of the chemical and a solid particle is made in the filter influent flow.

The alum may be pumped by a mechanical diaphragm, positive displacement pump. The dosage is manually adjusted by adjustment of the pump stroke length. Motor speed may be controlled by a silicon controlled rectifier (SCR) drive unit that uses a filter-flow signal to pace the pump in the automatic mode. The SCR drive is also equipped with a manual potentiometer for manual speed control and a meter indicating percentage of total or full motor speed.

The pump discharge check valve has a built-in back pressure device to prevent nonlinear delivery due to low discharge pressure and to prevent siphoning. All wetted parts of the pump are selected for their chemical resistance.

POLYMERS (POLYELECTROLYTES)

Polymers are flocculation aids which are classified on the basis of the type of electrical charge on the polymer chain. Polymers possessing negative charges are called "anionic," positive charged polymers are called "cationic," and polymers that carry no electrical charge are called "nonionic." Polymers cause the suspended material to stick together by chemical bridging or chemical enmeshment when contact is made in the filter influent flow.

Generally only the "anionic" polymers are used in conjunction with alum.

Polymer usually is injected into the influent line of the filters downstream from the point of alum injection.

The polymer may be prepared for use (dilution and aging) by a polyelectrolyte mixer unit. This unit consists of a dry polymer feeder with storage hopper, a solution-water flow meter with regulating valve, pressure regulating valve, pressure gage, solenoid valves, dilution water flow meter with regulating valve, polymer wetting cones, a mixing/aging tank, slow-speed mixer, transfer pump, metering/storage tank, and a metering pump with SCR drive.

The dry feeder is a screw-type feeder capable of metering dry polymer of densities ranging from 14 to 42 lbs/cu ft (225 to 675 kg/cu m) at an adjustable rate to the wetting cones in order to prepare various solution concentrations.

The mixing/aging tank and the metering/storage tank are sized based on the projected use of polymer. The tanks usually are made of steel and are provided with a fiberglass liner. The mixer, a low-shear type (to avoid breaking up floc), is fitted with a stainless steel shaft and impellers.

The slow speed, positive displacement, "progressing cavity" type transfer pump conveys the mixed polymer solution from the mixing/aging tank to the metering/storage tank with minimal polymer shear. The metering pump is capable of delivering various amounts of polymers at various percent solutions. Flow pacing, adjustment of the dosage rate, and operation of the polymer metering pump are the same as for the alum feed pump.

EXAMPLE 1

Known		Unknown
Polymer Delivered, lbs/day	= 72 lbs polymer/day	Polymer Dose, mg/*L*
Flow Through Filter, gpm	= 6000 gpm	

Determine pounds of polymer per million pounds of water which is the same as mg per million mg or mg/*L*.

$$\begin{aligned}\text{Polymer Dose, mg}/L &= \frac{\text{Polymer delivered, lbs polymer/day}}{\text{Flow through filter, M lbs water/day}}\\ &= \frac{72\text{ lbs polymer/day}}{6000\text{ gal/min} \times 8.34\text{ lbs/gal} \times 60\text{ min/hr} \times 24\text{ hr/day}}\\ &= \frac{72\text{ lbs polymer/day}}{72{,}057{,}600\text{ lbs water/day}}\\ &= \frac{72\text{ lbs polymer/day}}{72\text{ M lbs water/day}}\\ &= 1\text{ mg polymer/liter water}\\ &= 1\text{ mg}/L\end{aligned}$$

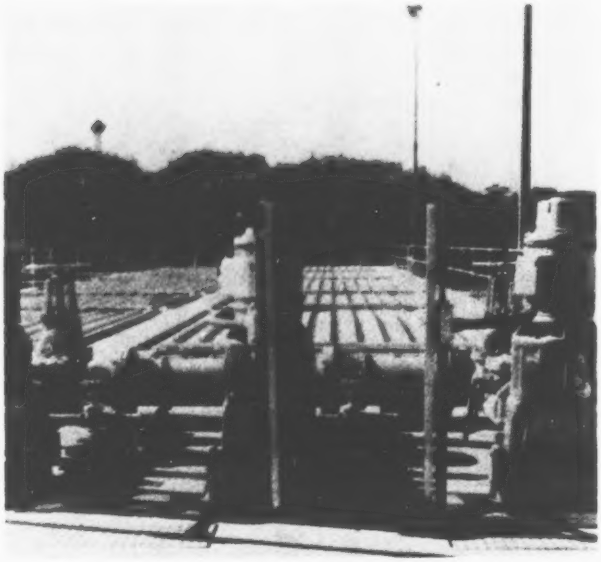


Fig. 3.26 Filter feed pumps

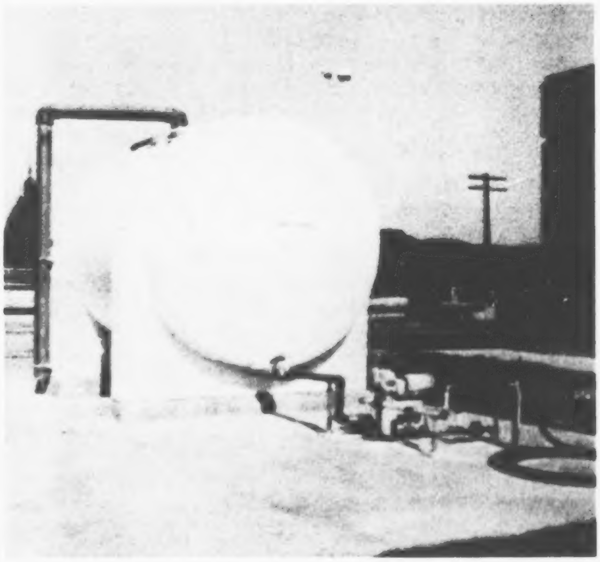


Fig. 3.27 Alum storage tank and feed pump

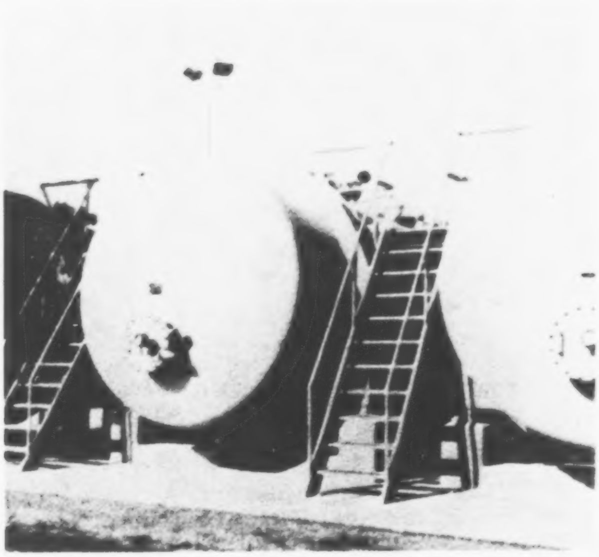


Fig. 3.28 Filter vessels

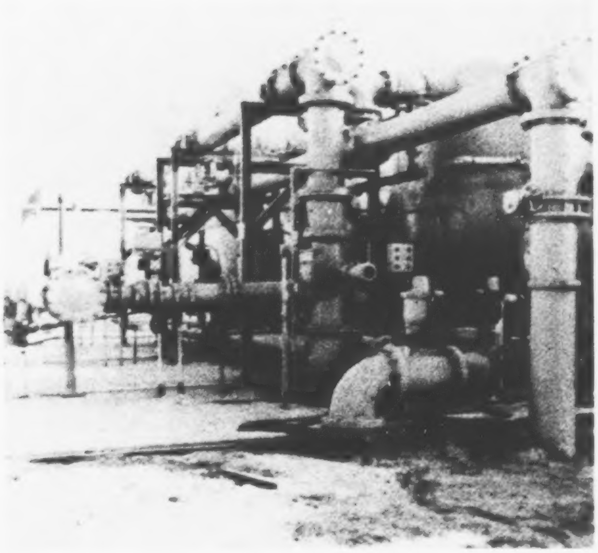


Fig. 3.29 Filter vessels

A variable-area flow meter (rotameter) is provided to indicate flow of dilution water to the metered polymer (Figure 3.30). The polymer is mixed automatically by the polyelectrolyte mixer. The dry feeder is calibrated to dispense a metered quantity of dry polymer to obtain a desired solution concentration. The dry polymer drops to the wetting cones from the feeder hopper, where it is spread on a high velocity water surface and the individual grains of polymer are wetted to form a polymer solution. This solution then flows to the aging tank where it is mixed and aged. On completion of the aging cycle, the polymer solution is pumped to the metering/storage tank by the transfer pump. When the aging tank empties, the polymer preparation and mixing cycle begins again. The metering pump, calibrated to deliver a desired dosage, draws the polymer solution from the metering/storage tank and delivers it to the influent line of the filters.

Steps to calculate polymer and alum dosage are outlined in the following examples. Information concerning the concentration of chemical (lbs/gal) delivered to your plant may be obtained from the chemical manufacturer or supplier.

EXAMPLE 2.

Determine polymer dosage, mg/*L*. Polymer is supplied to your plant at a concentration of 0.5 pounds polymer per gallon (60 gm/*L* or 60 kg/cu m). The polymer feed pump delivers a flow of 0.10 gpm (0.0063 *L*/sec) and the flow to the filter is 3,000 gpm (190 *L*/sec). Calculate the concentration or dose of polymer in the water applied to the filter.

Known		**Unknown**
Polymer Conc., lb/gal	= 0.5 lbs/gal	Polymer Dose, mg/*L*
Polymer Pump, gpm	= 0.1 gpm	
Flow to Filter, gpm	= 3000 gpm	

ENGLISH

Calculate polymer dose, mg/*L*

$$\begin{aligned}\text{Dose, mg/}L &= \frac{\text{Flow, gal/min} \times \text{Conc., lbs polymer/gal}}{\text{Flow, gal/min} \times 8.34 \text{ lbs water/gal}}\\ &= \frac{0.1 \text{ gal/min} \times 0.5 \text{ lbs polymer/gal}}{3000 \text{ gal/min} \times 8.34 \text{ lbs water/gal}}\\ &= \frac{0.05 \text{ lbs polymer}}{25{,}020 \text{ lbs water}} \times \frac{1{,}000{,}000^{*}}{1 \text{ M}}\\ &= \frac{2.0 \text{ lbs polymer}}{1 \text{ M lbs water}}\\ &= \frac{2.0 \text{ mg polymer}}{1 \text{ M mg water}^{**}}\\ &= 2.0 \text{ mg/}L\end{aligned}$$

---

* We multiplied the top and the bottom by the same number, 1,000,000 or 1 M. This is similar to multiplying the top and bottom by 1, you do not change the equation.

** 1 M mg water = 1 liter.

METRIC

$$\begin{aligned}\text{Dose, mg/}L &= \frac{\text{Flow, }L\text{/sec} \times \text{Conc., gm polymer/}L \times 1000 \text{ mg/gm}}{\text{Flow, }L\text{/sec}}\\ &= \frac{0.0063\ L\text{/sec} \times 60 \text{ gm polymer/}L \times 1000 \text{ mg/gm}}{190\ L\text{/sec}}\\ &= \frac{380 \text{ mg polymer/sec}}{190\ L \text{ water/sec}}\\ &= 2 \text{ mg/}L\end{aligned}$$

EXAMPLE 3. Determine alum dosage, mg/*L*

Liquid alum usually is supplied at a concentration of 5.4 pounds alum per gallon (650 gm/*L* or 650 kg/cu m). In this example, the alum feed pump delivers 88 ml per minute and the flow to the filter is 3,000 gpm (190 *L*/sec). Calculate the concentration or dose of alum in the water applied to the filter.

Known		**Unknown**
Alum Conc., lb/gal	= 5.4 lbs/gal	Alum dose, mg/*L*
Alum Pump, ml/min	= 88 ml/min	
Flow to Filter, gpm	= 3000 gpm	

ENGLISH

Calculate alum dose, mg/*L*

$$\begin{aligned}\text{Dose, mg/}L &= \frac{\text{Flow, ml/min} \times \text{Conc., lbs alum/gal} \times 0.00026 \text{ gal/ml}^{*}}{\text{Flow, gal/min} \times 8.34 \text{ lbs water/gal}}\\ &= \frac{88 \text{ ml/min} \times 5.4 \text{ lbs alum/gal} \times 0.00026 \text{ gal/ml}}{3{,}000 \text{ gal/min} \times 8.34 \text{ lbs water/gal}}\\ &= \frac{0.125 \text{ lbs alum}}{25{,}020 \text{ lbs water}} \times \frac{1{,}000{,}000}{1 \text{ M}}\\ &= \frac{5 \text{ lbs alum}}{1 \text{ M lbs water}}\\ &= 5 \text{ mg/}L\end{aligned}$$

---

* Conversion factor. 1 ml = 0.00026 gallons

METRIC

$$\begin{aligned}\text{Dose, mg/}L &= \frac{\text{Flow, ml/min} \times \text{Conc., gm polymer/}L \times 1000 \text{ mg/gm}}{\text{Flow, }L\text{/sec} \times 60 \text{ sec/min} \times 1000 \text{ ml/}L}\\ &= \frac{88 \text{ ml/min} \times 650 \text{ gm polymer/}L \times 1000 \text{ mg/gm}}{180\ L\text{/sec} \times 60 \text{ sec/min} \times 1000 \text{ ml/}L}\\ &= \frac{950 \text{ mg/sec}}{190\ L\text{/sec}}\\ &= 5 \text{ mg/}L\end{aligned}$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

3.4D What is the purpose of the holding tank?

3.4E Cross out the incorrect words within the following parentheses in order to make the statement correct.

Alum is used for *(COAGULATION OR FLOCCULATION)* while polymers are used for *(COAGULATION OR FLOCCULATION)*.

3.4F Polymer is supplied at a concentration of 0.6 pounds polymer per gallon (72 gm/*L* or 72 kg/cu m). The polymer feed pump delivers a flow of 0.15 gpm (0.0095 *L*/sec) and the flow to the filters is 5,000 gpm (135 *L*/sec). Calculate the concentration or dose of polymer in the water applied to the filter.

3.413 ***Filters*** (See Figure 3.25, page 155)

This section discusses the purpose of the parts of the filters.

VESSELS (Figure 3.28 and 3.29, page 157)

In our example, each pressure vessel containing filter media consists of a cylindrical shell closed at both ends. Manways are provided to allow entry to the vessel for media installation and maintenance work. Pressure gages are attached to the manway covers to facilitate monitoring of the vessel pressure.

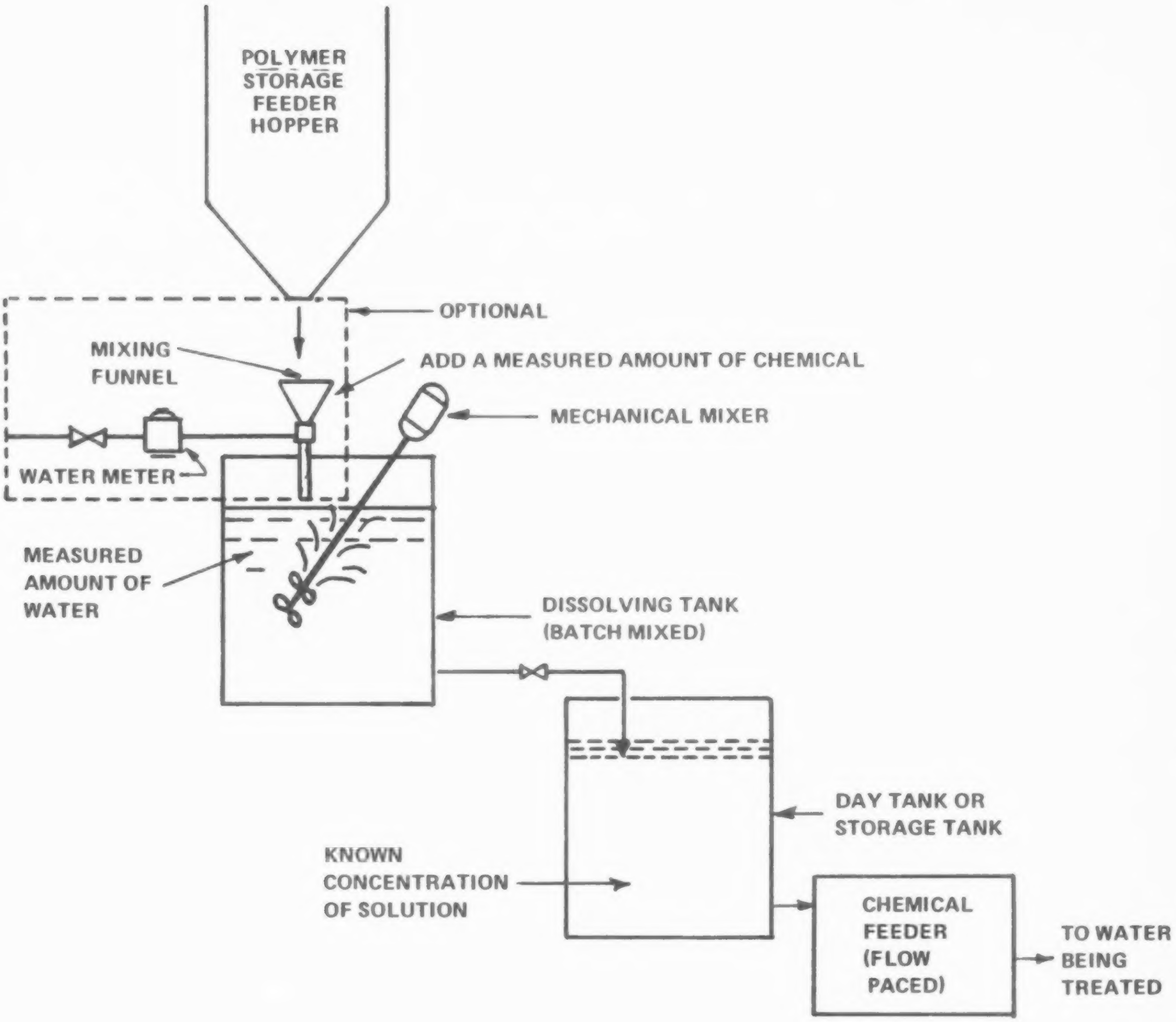

POLYMER STORAGE FEEDER HOPPER
OPTIONAL
MIXING FUNNEL
ADD A MEASURED AMOUNT OF CHEMICAL
MECHANICAL MIXER
WATER METER
MEASURED AMOUNT OF WATER
DISSOLVING TANK (BATCH MIXED)
DAY TANK OR STORAGE TANK
KNOWN CONCENTRATION OF SOLUTION
CHEMICAL FEEDER (FLOW PACED)
TO WATER BEING TREATED

Fig. 3.30 Polymer dissolver, day tank and feeder

A direct spring-loaded pressure relief valve is installed on top of the filter and is set to release at a preset pressure. The relief valve is provided to prevent vessel rupture in case effluent flow is restricted or stopped while influent flow continues.

A combination-type air-release valve with a large orifice is also installed on top of the filter to permit air to exhaust when the filter vessel is charged with water and to allow air to reenter when the filter vessel is drained. A small orifice is also provided to exhaust small pockets of air which may collect during operation of the filter.

INTERIOR PIPING (Figure 3.25, page 155)

Interior vessel surfaces, influent and effluent headers, and supports are painted with a protective coating to inhibit corrosion. The influent header is suspended and supported from the upper side of the vessel by lugs. Each filter is equipped with rotary surface wash arms that are installed and supported just beneath the influent header. These are self-propelling, revolving "straight line" wash arms.

The surface wash piping consists of an influent water line, solenoid valve, a central bearing of all-bronze construction, a bronze tee having a nozzle affixed to emit a water stream directly below and from the center of the tee, and arms extending laterally from the tee. The lateral arms are fitted with numerous brass nozzles located at double-angle positions to most effectively cover the area of the filter bed to be cleaned. Each nozzle is fitted with a synthetic rubber cap slitted to act as a check valve to keep filter media away from the nozzle.

Water to the wash arms is supplied from an external source, usually from the treatment plant wash water system. Water from the surface wash arms quickly breaks up the mat of suspended material that has accumulated in and on the top layer of filter media. This occurs during the first portion of the backwash cycle.

The effluent header is encased in concrete fill in the lower section of the filter. PVC underdrain laterals are attached to the effluent header. Each lateral has numerous small diameter holes facing toward the bottom of the filter. The ends of the laterals are capped. The filtered water is collected by the underdrain laterals which passes the water to the effluent header for discharge from the filter.

UNDERDRAIN GRAVEL (Support Media)

The inert filtering media is supported by underdrain gravel consisting of specifically sized, hard, durable, rounded stones with an average specific gravity of not less than 2.5. The gravel is placed in the filter in many specific layers starting with the larger stones (2-inch or 5-cm diameter) on the bottom and progressing to the smallest stones (¼-inch or 0.7-cm diameter) on top. The depth of each layer, specific stone sizes, and overall gravel depth will depend on the application, type, and quantity of inert media that will be used in a filter.

INERT MEDIA

Granular filter media commonly used in wastewater filtration include anthracite coal, silica sand, and garnet sand. These filter media range in size from 0.20 mm to 1.20 mm and specific gravities range from 1.35 to 4.5. The largest size media, anthracite coal, has the lowest specific gravity. Conversely, the smallest media, garnet sand, has the highest specific gravity.

Inert-media filter configurations vary according to the specific characteristics of the water to be filtered. The common applications use either silica sand or garnet sand as a single-media; anthracite coal and silica sand or garnet sand as a dual-media; and anthracite coal, silica sand, and garnet sand as a multi-media or mixed media filter.

In most filter applications, any of the various media used are placed in the filter with 60 percent of the larger size, lower specific gravity media on top, 30 percent of the medium size and specific gravity in the middle, and 10 percent of the smaller size, higher specific gravity media on the bottom. Thus, the smaller size filter media is placed on the support media first, followed by the medium size filter media and then the larger size filter media. Total filter media depth varies with the application.

Due to the size and density ratio of the media and its placement in the filter, the larger size and lower specific gravity media stay at the top and the smaller size higher specific gravity media remain at the bottom. Most dual-media filters are designed to keep the media separated after backwashing.

FLOW CONTROL METHOD (Figure 3.31)

In filter operation, the rate of flow through a filter is expressed in gallons per minute per square foot:

$$\begin{array}{c}\text{Rate of flow,}\\ \text{gpm/sq ft}\end{array} \sim \frac{\text{Driving force}}{\text{Filter resistance}} \sim \frac{\text{Total available head}}{\text{Total head loss}}$$

Therefore, as the total head loss increases, the ratio of flow decreases. The driving force refers to the pressure drop across the filter which is available to force the water through the filter. At the start of the filter run, the filter is clean and the driving force need only overcome the resistance of the clean filter media. As filtration continues, the suspended solids removed by the filter collect on the media surface or in the filter media, or both, and the driving force must overcome the combined resistance of the filter media and the solids removed by the filter.

The filter resistance (head loss) refers to the resistance of the filter media to the passage of water. The head loss increases during a filter run because of the accumulation of the solids removed by the filter. The head loss increases rapidly as the pressure drop across the suspended solids mat increases, because the suspended solids already removed compress and become more resistant to flow. As the head loss increases, the driving force across the filter must increase proportionally to maintain a constant rate of flow.

The constant-rate method of filtration is commonly used for pressure filters. In this method, a constant pressure is supplied to the filter and the filtration rate is then held constant by the action of a manually or automatically operated filter rate-of-flow controller. At the beginning of the filter run, the filter is clean and has little resistance. If the maximum available water pressure was applied to the filter, and the effluent flow was not restricted, the flow rate would be very high. To maintain a constant flow rate, some of the available pressure is dissipated by the rate of flow controller (RFC). At the start of the filter run, the RFC is nearly closed to provide the additional head loss needed to maintain the desired flow rate. As filtration continues, the filter gradually becomes clogged with suspended solids and the RFC opens proportionally. When the valve is fully opened, any further increase in the head loss will not be balanced by a corresponding decrease in the head loss of the RFC. Thus, the ratio of pressure to filter resistance will decrease, and the flow rate will decrease. This action is also known as filter differential pressure. When the flow rate decreases, filter differential pressure increases and this is an indication that the filter run must be terminated and a filter backwash should be initiated.

3.414 Backwash System

As the suspended material accumulates on the filter media surface, or in the filter media bed, or both, the differential pressure across the filter increases, flow through the filter decreases, and filter effluent quality deteriorates. The filter

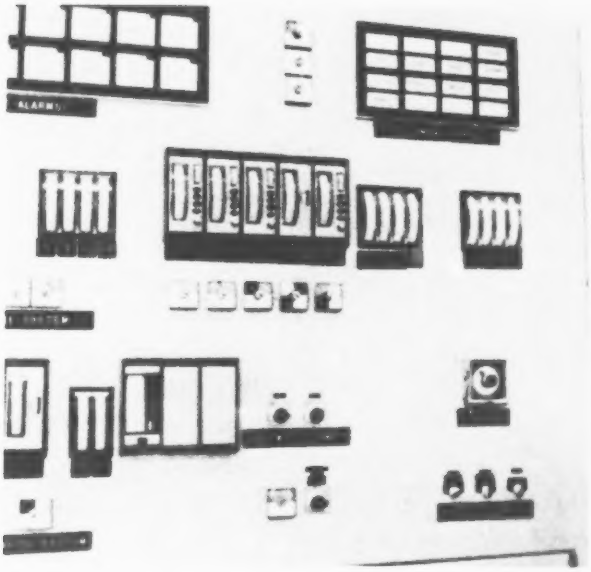


Fig. 3.31 Filter controls

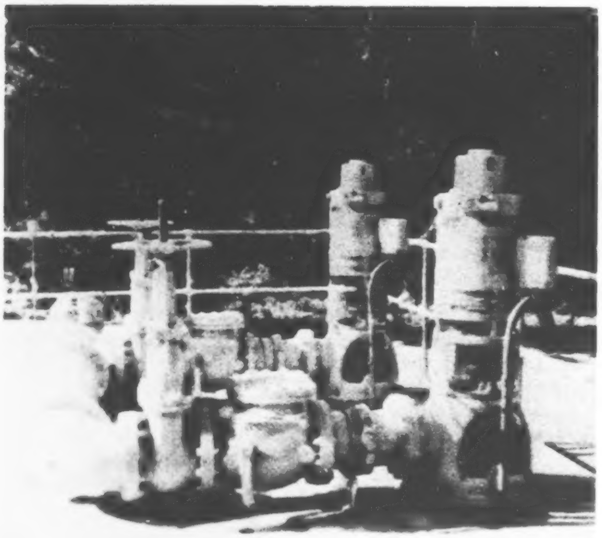


Fig. 3.32 Backwash pumps

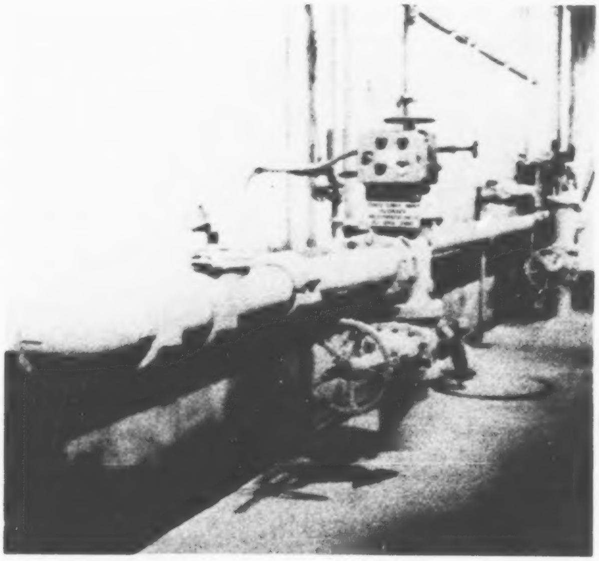


Fig. 3.33 Decant tank drain line automatic valves

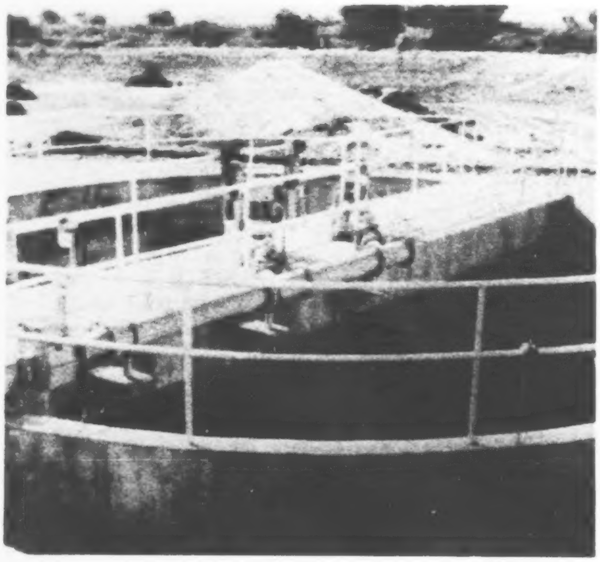


Fig. 3.34 Backwash recovery tank and feed pumps

backwash cycle removes the suspended solids accumulation from the filter, thus restoring the filter efficiency.

WET WELL

The backwash wet well is used to store a large volume of filtered and/or chlorinated wastewater to backwash the filters. The water, usually from the chlorine contact tank, flows to the wet well until it is filled up and then it flows to further final treatment processes. This flow method insures a continuous water supply to the wet well.

PUMPS (Figure 3.32, page 161)

The filter backwash pumps lift the filtered and/or chlorinated wastewater from the backwash wet well and pump it through the filters to remove the trapped suspended material. The pumps are generally of the vertical-turbine wet-pit type with either a closed or semi-open impeller. The pumps may be driven by fixed-speed motors.

The pump system is equipped with a solenoid-operated bypass valve installed on the common discharge line to prevent the possibility of the system operating at the shut-off pressure of the pumps. A pressure switch with an adjustable operating range (psi) will cause the valve to open upon rising pressure. The bypass flow is returned to the backwash wet well. The common discharge line is also equipped with an air relief valve that purges air from the system to prevent air slugs from disturbing the filter media bed.

Normal start-stop of the pumps may be controlled by means of current switches in the backwash program unit. Lead-lag position selector switches provide the means of selecting the sequence of starting for the pumps. A low water probe in the backwash wet well will stop the pumps in the event that the water level drops below a pre-set elevation.

The backwash pump common discharge line is provided with an orifice plate and flow-control valve. Flow control is accomplished by means of a cascade control system using a cam programmer to provide a setpoint signal. A cam is cut so as to gradually introduce the backwash flow to the filters, thereby avoiding sudden disturbance or uneven expansion of the filter media bed.

BACKWASH CYCLE

Whenever possible, the filters should be backwashed during the plant's low flow hours when the full capacity of the filters is not needed. The backwash cycle may be activated either manually, automatically by a pre-set filter differential-pressure level, or automatically by a program timer. In the manual mode, only a desired filter may be backwashed. In the automatic modes all filters in the system that are "ON LINE" may be washed when the differential pressure reaches the pre-set level. Upon completion of backwash of one filter, the next filter in an "ON LINE" status will begin to backwash.

The total backwash duration per filter usually is adjustable. The total backwash flow and duration should be adequate to fluidize and expand the media bed. The largest media size and the warmest expected water temperature will dictate the maximum filter backwash rates required.

When the backwash cycle is manually or automatically activated, the following sequence occurs:

1. Filter influent valve (V-1) and effluent valve (V-2) close to terminate filter feed flow. (See Figure 3.25, page 155, for locations of valves.)
2. Backwash influent valve (V-3) and effluent valve (V-4) open to allow backwash flow into and out of the filter.
3. The surface wash arms' influent water line solenoid valve (V-5) opens allowing the wash arms to function in initially breaking up the mat of suspended material that has accumulated on the top layer of filter media.
4. The backwash pumps start pumping against a closed backwash control valve. The backwash flow rate is brought up to full rate in one to two minutes as determined by the cam programmer transmitting a gradual "open" signal to the backwash flow-control valve operator.

   As the surface wash continues to operate, the backwash flow gradually enters the filter from the bottom. As the flow increases, the bed fluidizes and expands upward (about 20 percent of the total media depth) allowing a uniform rolling action of the filter media bed which results in cleaning of the media due to the hydrodynamic shear (water causes grains to clean each other) that occurs. The media bed expands upward and into the rotating surface wash arms. The arms now aid in breaking up the suspended material and mud balls that have accumulated in the top section of the media.
5. After two to five minutes of surface wash, the surface wash influent water line solenoid valve closes. Surface wash is discontinued two to ten minutes before the backwash ends so that the surface of the filter media will be smooth and level at the beginning of the cleaned filter run cycle.
6. After seven to twenty minutes of backwash, the backwash flow-control valve gradually begins to close. Shortly after the backwash flow-control valve is fully closed, the backwash pumps stop.
7. Backwash influent valve (V-3) and effluent valve (V-4) close.
8. Filter influent valve (V-1) and effluent valve (V-2) open.

NOTE: When the backwash cycle is activated, the filter flow-control valve fully closes. Upon completion of the cycle the valve opens slightly.

The valve sequence indicated in items 1, 2, 8 and 9 occurs simultaneously to insure that the filter does not become "air bound" (clogged by air released from water). Air binding will reduce or block filter influent flow and/or create media bed disturbance when filter backwash begins.

3.415 ***Decant Tank*** (Backwash Recovery) (Figures 3.33 and 3.34, page 161)

Most decant tanks are very similar to secondary clarifiers because they have flights or scrapers to collect settled material toward a sludge hopper.

Filter backwash effluent leaves the filter and may be discharged to the decant tank. The suspended material in the backwash water is allowed to settle and the clarifier effluent overflows to the holding tank through weir slots between the two tanks for recycle to the filters. The settled material is collected toward a hopper in the tank for periodic discharge to the solids handling facility.

If poor settling occurs in the decant tank, all spent backwash flow may be returned to the head end of the plant through the tank drain line. The drain line may be equipped with a propeller meter and a motor-operated butterfly valve. The common opening limit of the valve should be set to discharge tank flow at a rate which will not hydraulically overload the plant.

The tank may be equipped with high water level probes which will open the motor-operated valve fully to allow a predetermined volume of water to leave the tank rapidly. This may be necessary if the tank becomes surcharged (overloaded) due to frequent filter backwashes.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

3.4G List the major components of pressure filters.

3.4H How is the mat of suspended material on the media surface initially broken up during a backwash?

3.4I What is the source of water used to backwash the filter?

3.4J What is the purpose of the decant tank?

3.42 Operation

3.420 Operational Strategy

This lesson has covered some of the basic concepts of inert-media pressure filters used to remove suspended solids and turbidity from secondary effluents before chlorination.

If the filters become overloaded due to high suspended solids concentration, excessive plant flows, high chemical concentrations, or exposure to very cold temperatures, be prepared for the problems discussed in this section.

1. High suspended solids concentrations will cause a filter to plug up fast, thus requring very frequent filter backwashes. This will result in high recycle flow rates through the plant and eventually the filters. This problem may be eliminated or reduced by having adequate spent backwash storage capacity or by having a "closed" filter system that will allow for clarification and reuse of spent backwash water for subsequent backwashes.
2. If no backwash storage or "closed" system is provided, hydraulic surcharge (overload) on the upstream side of the filters will result. Provisions must be made for filter bypass and/or storage. If bypass is the only alternative, you should anticipate increased chlorine demands at the chlorine injection point as a result of the increase in unfiltered suspended material. Adjust the chlorine dosage to compensate for the greater demands.
3. By allowing suspended material to bypass the filters and enter the chlorine contact tanks, more frequent cleaning of these tanks will be required.
4. If higher than normal plant flows can be anticipated (rain), it would be a good idea to operate the filter holding tank/wet well at a lower water level to provide for additional water storage. This action will reduce the surcharge possibility on the upstream side of the filters. This preventive action should also be used if a filter must be taken out of service for repairs or inspection.
5. If liquid alum is used and it is exposed to cold temperatures, the liquid alum will start to crystallize and the delivery of alum to the filter influent flow will be seriously impaired. If climatic conditions of this type are common in your area, consider storing the alum in an enclosed, warm space.
6. If chemical feed pump check valves or anti-siphon devices fail, large quantities of chemical will be drawn into the filters. This will result in short filter-run times due to increased differential pressure across the filter when a polymer is the chemical involved. When excessive alum concentrations are involved, the alum will pass through the filter media and filter effluent turbidity and suspended solids values will increase due to the alum breakthrough.
7. Filter flow and differential pressure valves may be sensed by differential pressure cells. These cells are water-activated and are fed through small-diameter piping. During periods of extremely cold weather these cells could freeze and prevent proper functioning of the filter and control instruments. Heavy insulation and/or heat tape will prevent the water in the cell piping from freezing.

3.421 Abnormal Operation

Efficient filter operation is essential if your final effluent quality is to comply with the waste discharge requirements established for your plant. Table 3.2 lists a few of the more common filter operational problems and suggestions on how to correct them.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

3.4K What happens when large quantities of alum or polymer accidentally reach the filter?

3.4L What precautions should be taken in regions where freezing temperatures occur?

3.4M What could cause high operating filter differential pressures?

3.43 Maintenance

A comprehensive preventive maintenance program is an essential part of plant operations. Good maintenance will insure longer and better equipment performance. The following may be used as a guideline in performing the required maintenance on the pressure filter system.

A filter system performance test should be done monthly. This test will enable you to evaluate and determine if the pumps, valves, filters, and control instruments are functioning properly. If they are not, the proper corrective action must be taken. A sample performance test form for three filters is shown in Figure 3.35.

Filter media and interior vessel surfaces should be inspected quarterly. The filter should be backwashed just prior to the inspection. Some of the items to look for are:

1. Is the media surface fairly flat and level? If not, the surface wash time should be reduced.
2. Are there mudball formations on or in the media? If so, an increased surface wash time in conjunction with a lower backwash rate should bring the media back to a clean condition.
3. Are very small quantities of mid-filter media particles visible on the top layer media surface? This condition is normal (refer to Section 3.413, Filters, page 158).
4. Do the surface wash arms rotate freely and in the proper direction? If not, the trouble could be a defective central bearing and tee. Are any nozzles plugged? If so, they must be cleaned.

CAUTION: Wear goggles when observing the operation of the surface wash arms. The velocity of water produced from the wash arms is great and will kick up surface media.

TABLE 3.2 ABNORMAL FILTER OPERATION

ABNORMAL CONDITION	POSSIBLE CAUSE	OPERATOR RESPONSE
PUMPS Do not meet pumping requirements.	Insufficient motor speed.	Install higher rpm motors.
	Pump impeller improperly set in bowl of pump.	Set impeller as per manufacturer's instructions.
	Excessive filter-system head losses.	Air in filter system. Analyze problem and take corrective action such as install higher rpm motors, redesign pump station, redesign force main, redesign orifice plates.
	Broken pump shaft.	Replace.
FILTERS (GENERAL) High operating filter differential pressure.	Filled with suspended material.	Backwash filters at least once every 24 hours.
	Excessive chemical feed "binding" media.	Evaluate and reduce dosage. Backwash filter.
Water discharges from pressure-relief valve.	Effluent valve(s) blocked or closed.	Investigate and correct valve problem
	Foreign object lodged between valve and seat.	Secure filter and clean valve seat.
Water discharges from air-relief valve.	Air pocket in underdrain system (most common after a backwash).	Secure filter for 2 to 3 minutes to allow vessel water level to stabilize, return filter to service. Adjust filter feed and backwash valves to open and close simultaneously to keep vessel full of water.
MEDIA Support media upset.	Air slug forced out by the backwash flow.	Install air relief valve on backwash influent line.
	Backwash flow pumped too suddenly.	Install flow-control valve for regulated flow rates.
	Backwash flow rate too high.	Install valve stops or limiting orifices.
Mud ball formation. Media surface cracks.	Inadequate surface wash time.	Increase surface wash time. Check to insure arms are operating.
Backwash water dirty at end of wash cycle.	Insufficient backwash time.	Increase time until clean water appears.
Media surface uneven after backwash.	Surface wash too long.	Decrease surface wash time.

5. Is there a small amount of foreign matter on the media surface (plastic, cigarette butts)? This condition is fairly normal and is most prevalent at the extreme effluent end of the backwash effluent header. The foreign matter is carried away by the backwash water during the next backwash cycle. If a large accumulation of foreign matter develops, the matter will have to be removed by manual means.

6. Inspect all interior metal surfaces to insure that the corrosion-inhibitive protective coating is in good condition. If not, prepare the affected surface and reapply the proper coating. An epoxy tar is frequently used for this purpose.

At least once monthly, the backwash rate should be observed to insure that the flow rate is correct as specified by the manufacturer's backwash rate-flow curve and that the backwash flow is allowed to enter the filter at a regulated rate. Observe the backwash effluent flow. The water should be clear at the end of the wash cycle. If it is not, an increase in the wash time is indicated.

The flow rates for the chemical feed pumps should be checked at least every two weeks. Corrective adjustments should be made to maintain the proper flow rates.

3.44 Safety

Safety precautions for sedimentation tanks and pumps set forth in Chapters 5, 14, and 15 *(OPERATION OF WASTEWATER TREATMENT PLANTS)* should be observed when operating and maintaining this equipment in the pressure filter system.

In addition, the following safety precautions should be observed:

1. Wear safety goggles and gloves when working with alum or polymers. Flush away any alum or polymer that comes in contact with your skin with cool water for a few minutes.
2. Be very careful when walking in an area where polymer mixing takes place. When a polymer is wet, it is very slippery. Clean up polymer with a chlorine solution.
3. When inspecting the interior of a filter vessel:
   a. Insure that all flow-control instruments are in the "OFF" position and that all valves are in the "MANUAL" or "OFF" position. Position all valves to prevent flow from entering the filter.
   b. Always ventilate vessel. Open two manway covers. Install and start an exhaust blower in one manway to provide fresh air circulation before entering the filter.
   c. Check vessel atmosphere for toxic gases (hydrogen sulfide), explosive conditions (Lower Explosive Limit), and sufficient oxygen.
   d. Entering a filter vessel is a three person operation. Two must be outside the vessel whenever one person is inside.
   e. Wear a hardhat when working inside a filter or around the filter vessel piping to protect your head from injury.

3.45 Review of Plans and Specifications

As an operator you can be very helpful to design engineers in pointing out some design features that would make your job easier. This section attempts to point out some of the items that you should look for when reviewing plans and specifications for expansion of existing facilities or construction of new pressure filter systems.

1. The variable hydraulic and suspended solids load in secondary effluents must be considered in the design to avoid short filter runs and excessive backwash-water requirements.
2. A filter that allows penetration of suspended solids (a coarse-to-fine filtration system) is essential to obtain reasonable filter run lengths. The filter media on the influent side should be at least 1 to 1.2 mm in diameter.
3. Auxiliary agitation of the media is essential to proper backwashing. Surface washers should be installed.

DATE: 7-21-87 BY: REDNER & KETTLE

VALENCIA WRP FILTER AND FILTER FEED PERFORMANCE TESTS

Test	PUMPS RUNNING			Filters on			Discharge Through Filters, GPM				Holding Tank Level	Pressure at Pump Discharge	Filter Differential Pressure			FILTER EFFLUENT FLOW CONTROL VALVE, % OPEN		
#	1	2	3	1	2	3	1	2	3	TOTAL	FEET	PSI	1	2	3	1	2	3
1	on	off	off	on	off	off	1400			1400	7.8	1.5	6.5			100	0	0
2	off	on	off	on	off	off	1100			1100	8.3	3.0	8.3			100	0	0
3	off	off	on	on	off	off	970			970	8.5	3.5	9.5			100	0	0
4	on	on	off	on	on	off	850	1400		2250	8.5	—	9.0	5.0		100	100	0
5	on	on	off	on	on	on	725	1224	1000	2950	8.5	5.0	8.5	5.0	5.0	100	100	100
6	on	off	on	on	on	on	700	1200	1000	2900	8.5	5.2	8.5	5.0	5.0	100	100	100
7	off	off	on	on	on	on	625	1075	925	2625	8.5	3.0	8.5	5.5	5.5	100	100	100
8	on	on	on	on	on	on	900	1275	1150	3325	7.7	8.0	9.5	6.0	6.0	100	100	100
9	on	off	off	off	off	on			1150	1150	7.7	3.0			7.0	0	0	100
10	on	off	off	off	on	off		1300		1300	7.9	3.0		6.5		0	100	0
11	on	off	off	on	off	off	975			975	8.0	3.2	10.0			100	0	0

NOTE: The filter effluent flow control valve should be 100% open during the monthly test.

REMARKS:

Fig. 3.35 Filtration system performance test chart

4. The effect of recycling used backwash water through the plant on the filtration rate and filter operation must be considered in predicting peak loads on the filters and resulting run lengths.
5. The filtration rate and head loss should be selected to achieve a minimum filter run length of 6 to 8 hours during peak-load conditions. This requirement will mean an average filter run length of 24 hours. Estimates of head loss development and filtrate quality should be based on pilot-scale observations of the proposed facility conducted at the treatment plant before the full-scale facility is designed.
6. Manways should be sized large enough to allow operators and equipment ease of entering and leaving the filter.
7. A media core sample port(s) should be provided to allow evaluation of the entire media depth.
8. Ladders and walkways should be provided to allow easy access to vessels, pipes, and valves.
9. Filter-flow charts should be provided to aid in monitoring filter performance.

3.46 Acknowledgments

1. County Sanitation Districts of Los Angeles, Valencia Water Reclamation Plant.
2. Mr. Jerry Schmitz, Draftsman, County Sanitation Districts of Los Angeles.

3.5 ADDITIONAL READING

1. *WASTEWATER FILTRATION DESIGN CONSIDERATIONS*, EPA Technology Transfer Seminar Publication, July 1974, U.S. Environmental Protection Agency, Center for Environmental Research Information (CERI), 26 West St. Clair Street, Cincinnati, Ohio 45268.
2. *PROCESS DESIGN MANUAL FOR SUSPENDED SOLIDS REMOVAL*, Technology Transfer, U.S. Environmental Protection Agency, Center for Environmental Research Information (CERI), 26 West St. Clair Street, Cincinnati, Ohio 45268.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

3.4N What safety precautions should be taken when working with alum or polymers?

3.4O How frequently should a filter system performance test be conducted?

3.4P What caution should be exercised when observing the operation of the surface wash arms?

END OF LESSON 4 OF 4 LESSONS
ON
PHYSICAL-CHEMICAL TREATMENT

DISCUSSION AND REVIEW QUESTIONS

(Lesson 4 of 4 Lessons)

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 3.

19. How are floatable and settleable solids removed from a holding tank?
20. How would you attempt to control corrosion of the interior surfaces of a pressure-filter vessel?
21. During what time of the day should the filters be backwashed?
22. What is the impact on downstream treatment processes if suspended solids get past the filtration system?

PLEASE WORK THE OBJECTIVE TEST NEXT.

SUGGESTED ANSWERS

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

Answers to questions on page 109.

3.0A NPDES stands for National Pollutant Discharge Elimination System.

3.0B Some locations have stringent discharge requirements because more and more wastes are being discharged into the receiving waters and increasing demands are being placed on the waters by water users.

3.0C Solids can be removed from secondary effluents by the addition of chemicals to cause coagulation and sedimentation, microscreens and gravity and pressure filters.

Answers to questions on page 112.

3.1A Chemicals may be added to reduce emergency problems such as those created by sludge bulking in the secondary clarifier, upstream equipment failure, accidental spills entering the plant, and seasonal overloads. Chlorine is the most common chemical used for disinfection.

3.1B When adding chemicals upstream from a biological treatment process, be sure that the chemical or its concentration is not toxic to the organisms treating the wastewater in the biological process.

Answers to questions on page 112.

3.1C The four most common chemicals added to improve settling are alum, ferric chloride, lime and polyelectrolytes (polymers).

3.1D Alum should be kept dry to prevent it from caking into a solid lump.

3.1E All mechanical equipment, such as conveyors, should be run until well-cleaned of all alum before shutting down because the alum can harden and jam the equipment.

Answers to questions on page 113.

3.1F Safety precautions required for handling ferric chloride in concentrated forms should be the same as those for acids. Wear protective clothing, face shields and gloves. Flush off all splashes on clothing and skin immediately.

3.1G Rubber or flexible piping with easy access and short runs will permit cleaning by squeezing the walls and washing out the broken scale. Solid piping that is plugged by scale usually requires replacement.

3.1H Clean up polyelectrolyte spills immediately. Polyelectrolytes will create an extremely slippery surface when wet.

3.1I Polyelectrolyte spills can be cleaned up by using chlorine. To clean up a spill, neutralize the polyelectrolyte with either salt (NaCl), liquid bleach or HTH powder.

Answers to questions on page 114.

3.1J Chemical solutions are prepared for feeding by mixing known amounts of chemicals and water together using a mechanical mixer. The resulting solution is stored in a day tank (holding tank) from which it is metered out at the proper dosage into the water being treated.

3.1K Common types of chemical feeders or metering equipment include:

1. Positive displacement pumps such as the piston pump, diaphragm pump, gear pump and progressive cavity pump;
2. Screw feeder;
3. Vibrating trough;
4. Rotary feeder; and
5. Belt-type gravimetric feeder.

Answers to questions on page 122.

3.1L Items that should be considered when selecting a chemical feeder include:

1. Total operating range.
2. Accuracy.
3. Repeatability.
4. Resistance to corrosion.
5. Dust control.
6. Availability of parts.
7. Safety.

3.1M The following information regarding a chemical feeder operation should be recorded:

1. Flows;
2. Characteristics of wastewater before and after treatment; and
3. Dosage and conditions of chemical treatment.

Answers to questions on page 127.

3.1N Factors that can cause a change in chemical dose requirements include:

1. Day of the week (weekdays or weekends);
2. Season of year (temperature and seasonal loadings); and
3. Year to year (changes resulting from industrial and population growth).

3.1O The most common method used to determine coagulation dosages is by running the jar test.

3.1P The jar test is an attempt to duplicate or simulate plant conditions by using laboratory equipment.

Answers to questions on page 128

3.1Q Water quality indicators that should be monitored when operating a chemical treatment process include alkalinity, pH, temperature, turbidity and suspended solids.

3.1R Abnormal conditions that could be encountered in the water being treated when operating a chemical treatment process include high solids, high or low flows, and change in pH and temperature.

3.1S Problems that could occur when operating a chemical treatment process include no coagulation (solids not settling out) and foaming.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 132.

3.2A Microstraining is a form of filtering used to clarify water by filtering out microscopic or very small suspended solids.

3.2B Microfabric is usually made of stainless steel wire, polyester, nylon cloth or plastic.

Answers to questions on page 133.

3.2C Major components of a typical microscreen include drum, microfabric, water spray system, solids waste hopper, drum drive units, ultraviolet lights, structure and bypass weir.

3.2D Ultraviolet lights are used to reduce biological growths on the microfabric. These growths can survive the water spray cleaning and will eventually clog the fabric.

Answers to questions on page 133.

3.2E Before starting a microscreen unit, inspect the electrical installation to be sure the controls are properly covered, fuses properly sized, and proper safety lock outs have been installed.

3.2F Items that should be included in the log of the operation of a microscreen include:

1. Hours of operation,
2. Volume of water processed, gallons or cubic meters,
3. Rate of application, gpd or cu m/day,
4. Applied suspended solids and BOD, lbs or kg/day,
5. Effluent suspended solids and BOD, lbs or kg/day,
6. Percent removal of suspended solids and BOD, %,
7. Chemicals added, pounds or kilograms,
8. Head loss through screen, inches or centimeters,
9. Maintenance performed on the unit, and
10. Remarks of special observations.

Answers to questions on page 135.

3.2G Abnormal conditions that could be encountered when operating a microscreen include:

1. High or low flows;
2. High solids loadings;
3. High or low pH values; and
4. High concentrations of oil and grease.

3.2H Problems caused by high or low pH levels include:

1. A high pH may result in the buildup of mineral deposits that will plug the fabric holes.
2. A rapid pH change may upset upstream treatment processes, thus increasing solids loadings.
3. A low pH may result in the corrosion of metal, especially the microfabric.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 136.

3.3A A gravity filter should be cleaned when (1) the pressure drop (head loss) across the bed becomes so great that the flow is reduced, or (2) increased solids are observed in the effluent.

3.3B Most filters operate on a batch basis whereby the filter operates continuously until its capacity to remove solids is reached. At this time it is completely removed from service and cleaned.

Answers to questions on page 137

3.3C Meanings of the following terms are:

1. Downflow. Water flows down through the bed.
2. Static bed. Bed does not move or expand while water is being filtered.

3.3D
1. In surface straining, the filter is designed to remove the solids at the very top of the media.
2. Depth filtration is designed to pull the solids deep into the media, thereby capturing the solids within as well as on the surface of the media.

Answers to questions on page 144.

3.3E Materials used for filter media include silica sand, antracite coal, garnet or ilmenite. Garnet and ilmenite are commonly used in multi-media beds.

3.3F If the filter media is not thoroughly cleaned during each backwashing, a buildup of solids will occur. The end result of incomplete cleaning is the formation of mudballs within the bed.

3.3G If nonfiltered water is supplied to the backwash system, clogging of the underdrain system may occur.

3.3H Used backwash water holding tanks are needed to prevent hydraulically overloading the treatment plant when backwash waters are returned to the headworks.

Answers to questions on page 146.

3.3I The head loss through the filter media is determined by measuring the water pressure above and below the filter media. When water flows through the media the pressure below the media will be less than the pressure above the media (when the pressure levels are measured or read at the same elevation).

3.3J Filter system alarms should be tested for proper functioning at least every 60 days.

Answers to questions on page 148.

3.3K A pre-start check should be conducted before starting filtering systems to prevent damage to the equipment and/or injury to personnel.

3.3L The purpose of the rate-control valve is to maintain the desired flow through the filter and prevent the backwash water from entering the filtered water during backwashing.

3.3M A filter should be backwashed after the capacity of the media to hold solids is well used up, but before solids break through into the effluent.

Answers to questions on page 149.

3.3N Abnormal operating conditions include:

1. High solids in applied water due to bulking sludge, rising sludge, or solids washout in the secondary clarifier.
2. Low suspended solids in applied water; however, solids pass through filter.
3. Loss of filter aid chemical feed.
4. High wet weather peak flows.
5. Low applied water flows.
6. High color loading.
7. High water temperature.
8. Low water temperature.
9. Air binding.
10. Negative pressure in filter.
11. High BOD and COD.
12. High coliform group bacteria levels.
13. Chlorine in applied water.
14. pH change in applied water.
15. High grease and oil in applied water.

3.3O To treat a high solids content in the water applied to a filter:

1. Run jar tests and adjust chemical dosage as needed;
2. Place more filters in service to prevent breakthrough; and
3. Prepare to backwash more frequently.

Answers to questions on page 151.

3.3P To determine if media are being lost, every three or four months measure and record the freeboard to the filter media surface. A small amount of media loss is normal, but an excessive amount (2 to 3 inches or 5 to 7 centimeters) indicates operational problems.

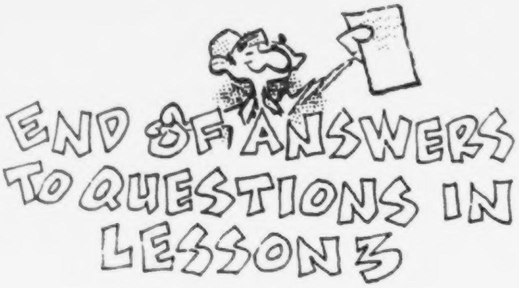
3.3Q Trees and shrubs should be kept away from uncovered filters because leaves will drop into the filter and they are very difficult to backwash out of the media.

Answers to questions on page 153.

3.3R The three main types of safety hazards around filtration systems are electrical, chemical and mechanical.

3.3S Filtration instrumentation should measure and record applied flows, backwash flows, head loss, and water quality before and after filtration.

3.3T Install all read-out meters, charts and gages of instruments in a convenient and centralized location.



Answers to questions on page 154.

3.4A The purpose of the inert-media pressure filter is to remove suspended solids and turbidity from secondary effluents to meet waste discharge requirements established by NPDES permits.

3.4B Chemicals commonly used with the filtration process are polymers and/or alum. The chemicals are used as coagulants for the solids and turbidity to aid in their removal by filtration.

3.4C Major components of a pressure filtration system include:

1. A holding tank or wet well;
2. Filter feed pumps;
3. Chemical coagulant feed pump system;
4. Filters;
5. Filter backwash wet well;
6. Filter backwash pumps; and
7. Decant tank.

Answers to questions on page 158.

3.4D The purpose of the holding tank is to store water and to allow additional settling of the suspended solids before the water is applied to the filter.

3.4E Alum is used for *COAGULATION* while polymers are used for *FLOCCULATION*.

3.4F **Known** **Unknown**

Polymer Conc., lb/gal = 0.6 lbs/gal
Polymer Pump, gpm = 0.15 gpm
Flow to Filter, gpm = 5,000 gpm

Polymer Dose, mg/*L*

ENGLISH

Calculate polymer dose, mg/*L*.

$$\text{Dose, mg}/L = \frac{\text{Flow, gal/min} \times \text{Conc., lbs polymer/gal}}{\text{Flow, gal/min} \times 8.34\text{ lbs water/gal}}$$

$$= \frac{0.15\text{ gal/min} \times 0.6\text{ lbs polymer/gal}}{5{,}000\text{ gal/min} \times 8.34\text{ lbs/gal}}$$

$$= \frac{0.09\text{ lbs polymer}}{41{,}700\text{ lbs water}} \times \frac{1{,}000{,}000}{1\text{ M}}$$

$$= 2.2\text{ mg}/L$$

METRIC

$$\text{Dose, mg}/L = \frac{\text{Flow, }L\text{/sec} \times \text{Conc., gm polymer}/L \times 1{,}000\text{ mg/gm}}{\text{Flow, }L\text{/sec}}$$

$$= \frac{0.0095\ L\text{/sec} \times 72\text{ gm polymer}/L \times 1{,}000\text{ mg/gm}}{315\ L\text{ water/sec}}$$

$$= 2.2\text{ mg}/L$$

Answers to questions on page 163.

3.4G Major components of pressure filters include:

1. Vessels;
2. Interior piping;
3. Underdrain gravel (supporting media);
4. Inert media; and
5. Flow controls.

3.4H Water from the surface arms initially breaks up the mat of suspended material on the media surface.

3.4I The water used to backwash the filter comes from the chlorine contact tank (filtered and chlorinated) to the backwash wet well before it is used for backwashing.

3.4J The decant tank receives the backwash water from the filters. The backwash water is allowed to settle and the clarified effluent is recycled to the filters. The settled material is collected and discharged to the solids handling facility.

Answers to questions on page 163.

3.4K When a large quantity of polymer reaches a filter, short filter-run times will result due to increased differential pressure across the filter. When excessive alum concentrations are involved, the alum will pass through the filter media and filter effluent turbidity and suspended solids will increase due to alum breakthrough.

3.4L In areas where freezing temperatures occur, heavy insulation and/or heat tape will prevent the water in the cell piping from freezing. Also liquid alum should be stored in an enclosed, warm space.

3.4M High operating differential pressures could occur if either (1) the media is filled with suspended material; and/or (2) excessive chemical feed is "binding" the media.

Answers to questions on page 166.

3.4N Safety precautions that should be taken when working with alum or polymers include:

1. Wear safety goggles and gloves when working with alum or polymers. Flush away any alum or polymer that comes in contact with your skin with cool water for a few minutes.
2. Be very careful when walking in an area where polymer mixing takes place. When a polymer is wet, it is very slippery.

3.4O Filter system performance tests should be conducted monthly.

3.4P Wear goggles when observing the operation of the surface wash arms.

END
OF
ANSWERS
TO
QUESTIONS
IN
LESSON
4...

OBJECTIVE TEST

Chapter 3. PHYSICAL-CHEMICAL TREATMENT

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

1. Ferric chloride is corrosive.
   1. True
   2. False
2. Safety precautions required for handling ferric chloride in concentrated forms should be the same as those for acids.
   1. True
   2. False
3. An overdose of a polyelectrolyte to a secondary effluent containing solids can be worse than no polyelectrolyte addition at all.
   1. True
   2. False
4. A progressive cavity pump may operate without feed material and not be damaged.
   1. True
   2. False
5. A coagulant may be used to precipitate phosphate as well as to remove solids from the water being treated.
   1. True
   2. False
6. Good housekeeping around chemical feeding systems is very important to good operations, but not important to safety.
   1. True
   2. False
7. If the microscreen drum is not rotating when the process water first enters the microscreen, the fabric may plug and be damaged.
   1. True
   2. False
8. Apply chlorine to control biological growths on the microfabric.
   1. True
   2. False
9. Rapid-sand filters may use either an upflow or a downflow backwashing process.
   1. True
   2. False
10. Downflow filters are designed to remove suspended solids by either the surface-straining method or the depth-filtration method.
    1. True
    2. False
11. The conventional single-media filter bed commonly used in potable water systems is generally unsatisfactory in removing solids found in wastewater because of plugging.
    1. True
    2. False
12. The finer, dense sand is placed over the coarse media (anthracite) in a dual-media filter.
    1. True
    2. False
13. Chlorine will not interfere with polyelectrolytes.
    1. True
    2. False
14. Dry filter media can be backwashed without any problems.
    1. True
    2. False
15. Alum is injected into the influent line of the filters downstream of the point of polymer injection.
    1. True
    2. False
16. Solids can be removed from secondary effluents by
    1. Activated sludge process.
    2. Addition of chemicals.
    3. Chlorination.
    4. Filtration.
    5. Microscreens.
17. Chemicals used to improve the settling of solids include
    1. ABS.
    2. Alum.
    3. Cations.
    4. Lime.
    5. Soda water.
18. Which of the following items should be inspected or checked before starting a chemical feeder?
    1. Direction of rotation of moving parts in motors
    2. Operation of control lights on control panel
    3. Operation of safety lock-out switches
    4. Proper voltage
    5. Size of overload protection
19. A jar test can be used to determine
    1. The most economical coagulation dosages.
    2. The number of jars of chemicals.
    3. The pH of a sample.
    4. The plant conditions by using laboratory equipment.
    5. What the clarity will probably be in the plant effluent.

20. Microstraining is capable of
    1. Disinfecting the effluent.
    2. Improving the effectiveness of the disinfectant.
    3. Removing soluble BOD.
    4. Reducing the coliform group organisms in the water being treated.
    5. Reducing the organic loading on the receiving waters.

21. Possible corrective actions to solve microscreen problems when treating high concentrations of oil and grease include
    1. Adding chemicals to improve oil and grease removals.
    2. Decreasing the drum rotation speed.
    3. Decreasing the water spray pressure.
    4. Placing fewer microscreens in service.
    5. Reducing oil and grease loadings at source.

22. Why should an empty filter not be filled through the inlet valve?
    1. Filling the backwash troughs in an empty filter places an unnecessary loading on the troughs.
    2. Question wrong. An empty filter should be filled through the inlet valve.
    3. This is a waste of production water.
    4. Untreated water will be discharged from the filter.
    5. Water falling onto the media will disturb the bed.

23. Indications of a disturbed or damaged filter underdrain include
    1. Boiling areas and quiet areas of the filter media during backwashing.
    2. Filter media in the effluent.
    3. Poor quality effluent suspended solids.
    4. Reduced effluent chlorine requirements.
    5. Reduction in effluent MPN.

24. Information that can be obtained from the head loss indicator on a rapid-sand filter includes
    1. Depth of filter media.
    2. Effectiveness of the backwash operation.
    3. Efficiency of BOD removal.
    4. Present condition of sand filter.
    5. Turbidity in the effluent.

25. Which of the following items should be included in your checklist for starting filtering systems?
    1. Backwash frequently to reduce head loss.
    2. Check motors for proper rotation.
    3. Fill tanks and piping and look for leaks.
    4. Inspect pumps and motors for excessive vibration.
    5. Inspect the total system for safety hazards.

26. Which of the following items would you check if laboratory tests indicated high turbidity and suspended solids in the effluent of a filter?
    1. Check for excessive head loss.
    2. Determine filter aid dosages.
    3. Examine backwash cycle for complete wash.
    4. Inspect for damaged bed due to backwashing.
    5. Look for fluctuating flows that could cause breakthrough.

27. What conditions determine the backwash rate for a pressure filter?
    1. Largest media size
    2. Quality of the backwash water
    3. Settleability of solids in the secondary clarifier
    4. Suspended solids concentrations in the water applied to the filter.
    5. Warmest expected water temperature

28. Which of the following conditions can cause operational problems with a pressure filter?
    1. Excessive plant inflows
    2. High chemical concentrations
    3. High coliform MPNs
    4. High suspended solids concentrations
    5. Very cold temperatures

29. Factors that could upset the support media of a pressure filter include
    1. Air slug forced out by backwash flow.
    2. Backwash flow rate too high.
    3. High suspended solids concentrations in the water applied to the filter.
    4. Pumping backwash flow too suddenly.
    5. Surface wash too long.

30. Factors that should be considered when reviewing plans and specifications for new pressure filters include
    1. Filter media that allows penetration of suspended solids in order to obtain reasonable filter run lengths.
    2. Hoists to allow for inspection and maintenance of air headers.
    3. Ladders and walkways to allow easy access to vessels, pipes and valves.
    4. Manways sized large enough to allow operators and equipment ease of entering and leaving filters.
    5. Media core sample ports to evaluate entire depth of media.

CORRECT
WRONG
WRONG
WRONG
CORRECT
CORRECT
CORRECT
WRONG
CORRECT
WRONG
CORRECT
WRONG
CORRECT

END OF OBJECTIVE TEST

CHAPTER 4

INSTRUMENTATION

by

George Ohara

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OBJECTIVES

Chapter 4. INSTRUMENTATION

After completion of Chapter 4 you should be able to do the following:

1. Describe the need for instrumentation and controls,
2. Indicate the variables or values measured by instruments and how they are measured,
3. Identify a controller and describe its purpose,
4. Identify recorders — indicators and describe their purpose,
5. Read instruments and controls and make proper adjustments in operation of treatment plant,
6. Determine location and cause of instrument and control failures and take corrective action, and
7. Maintain instruments and controls.

ALWAYS REMEMBER: If you don't know what you are doing, *HANDS OFF!*

GLOSSARY

Chapter 4. INSTRUMENTATION

HYDROSTATIC SYSTEM HYDROSTATIC SYSTEM

In a hydrostatic sludge removal system, the surface of the water in the clarifier is higher than the surface of the water in the sludge well or hopper. This difference in pressure head forces sludge from the bottom of the clarifier to flow through pipes to the sludge well or hopper.

OFFSET (or DROOP) OFFSET

The difference between the actual value and the desired value (or set point) characteristic of proportional controllers that do not incorporate reset action.

PROCESS VARIABLE PROCESS VARIABLE

A physical or chemical quantity which is usually measured and controlled.

SET POINT SET POINT

The position at which the control or controller is set. This is the same as the desired value of the process variable.

SOFTWARE PROGRAMS SOFTWARE PROGRAMS

Computer programs designed and written to monitor and control wastewater treatment processes or other processes.

TIME LAG TIME LAG

The time required for processes and control systems to respond to a signal or to reach a desired level.

CHAPTER 4. INSTRUMENTATION

(Lesson 1 of 4 Lessons)

4.0 NEED FOR INSTRUMENTATION AND CONTROLS

With today's tougher discharge and monitoring requirements, more and more wastewater treatment plants are being designed and constructed with sophisticated instrumentation and control systems to help operators do their job. Consequently, this chapter on instrumentation and controls is dedicated to familiarizing the operator with the role instruments and controls play in the operation of a wastewater treatment plant. We will define instruments and controls, what they do, how they do their job, how they are related to plant operations, and the care they should receive. This chapter will not attempt to cover the theory of instruments and controls, their design, construction, and repair. These matters are best left to qualified instrument personnel that have the necessary training, experience, and equipment to do the job. So let's get started!

4.00 What are Instruments and Controls?

Simply stated *AN INSTRUMENT IS NOTHING MORE THAN A MEASURING DEVICE.* Let's look at a few samples.

One of the simplest and most common examples of a measuring device is the rule or tape measure. Rulers are used to measure linear (lengthwise) distances. The distances may be measured in the terms of inches, feet, fractions, decimals or in metric units. Depending upon the job we have to do, we may choose to use a 6-inch pocket scale or a 100-foot tape measure as a measuring device (Fig. 4.1).

Another common and familiar instrument is the clock or wrist watch which we use to measure time. We may measure time in units of seconds, minutes, hours or days, depending upon our needs. The clock may be mounted on a building for all to see or it may be a wrist watch for personal use (Fig. 4.2).

Another common instrument is the bathroom scale that we use to measure our weight. Scales may measure in terms of pounds and ounces, pounds and decimals of a pound, or in grams in the metric system. There are many different types of scales used to measure weight. A postage scale (Fig. 4.3) used to weigh letters cannot be used to weigh groceries nor can the scale used to weigh chlorine containers be used to weigh the small amounts of solid residues measured in the lab.

An instrument is selected on the basis of a particular job it has to do.

In review of what has been discussed, we may simply state that instruments are measuring devices. They may directly or indirectly measure many quantities whose values or changes in values are both necessary and useful information for operating a treatment plant.

Next, let us describe controls and their uses. Simply stated *CONTROLS ARE DEVICES OR A SERIES OF DEVICES THAT EFFECT SOME CHANGE DUE TO SOME OTHER CHANGE IN CONDITIONS.*

One of the most sophisticated and common control systems is the human body. An example of this concept is a person opening a door. We can designate the eyes as a sensing instrument to determine (measure) whether the door is closed or open and the nervous system as a transmission system (message sending-receiving device). The brain is the control logic and the arms-hands are the control output. We can simulate a control system as follows:

1. The eyes measure the door as closed.
2. The eyes transmit a signal to the brain whose logic has been established for "door open."
3. The brain, receiving the signal coded as "closed door," institutes an action to open the door.
4. The brain transmits a coded signal to the arm and hand calling for turning of the door knob and opening the door.
5. The eyes then measure the door as opened and transmit a signal coded as "satisfactory" to the brain ending this particular control sequence.

An example of a simple household control system is the thermostatically controlled heating system in your house. In this case the thermostat (Fig. 4.4), which is a temperature measuring and sensing device, sends an electrical signal to the heater causing it to fire up whenever the room temperature drops below a pre-determined level. After the rooms have warmed up to the pre-determined level, the thermostat stops sending an electrical message to the heater (Fig. 4.5) and the heater will shut down automaticaly. The control process may be analyzed as follows:

1. The thermostat senses the temperature has dropped below 70°F (21°C) and trips an electrical relay.
2. The relay transmits an electrical message to the heater's fuel regulation system where another device (solenoid) turns the fuel source to the "ON" position; this causes the heater to "light up" and produce heat.
3. After a period of heating, the room warms up to 70°F (21°C) or slightly more and causes the thermostat to cease sending an electrical signal to the heater's fuel regulation system. This, in turn, causes the heater to go "OFF" and prevents overheating of the room.
4. The whole sequence will repeat itself when the room temperature again falls below 70°F (21°C).

So far we have discussed a sophisticated biological control system, the human body, and a simple electrical control system. Next let us examine a simple hydro-mechanical control system that is familiar to all of us.

The toilet bowl flush tank uses a simple hydraulic and mechanical control system. When the bowl is flushed and the tank is empty, the tank starts to fill up automatically. Also, the tank

Fig. 4.1 Rulers and tape measures are common devices used to measure length.

Fig. 4.2 Clocks are instruments that measure time.

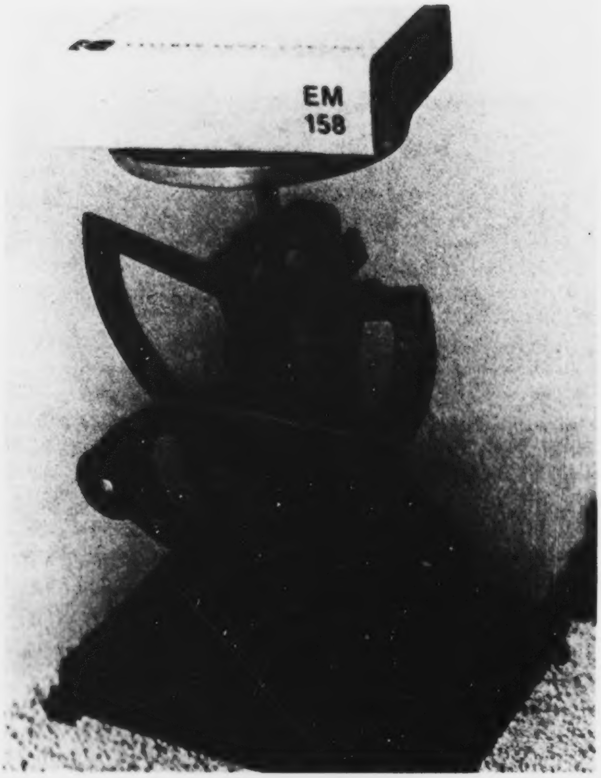


Fig. 4.3 A postage scale measures weight.

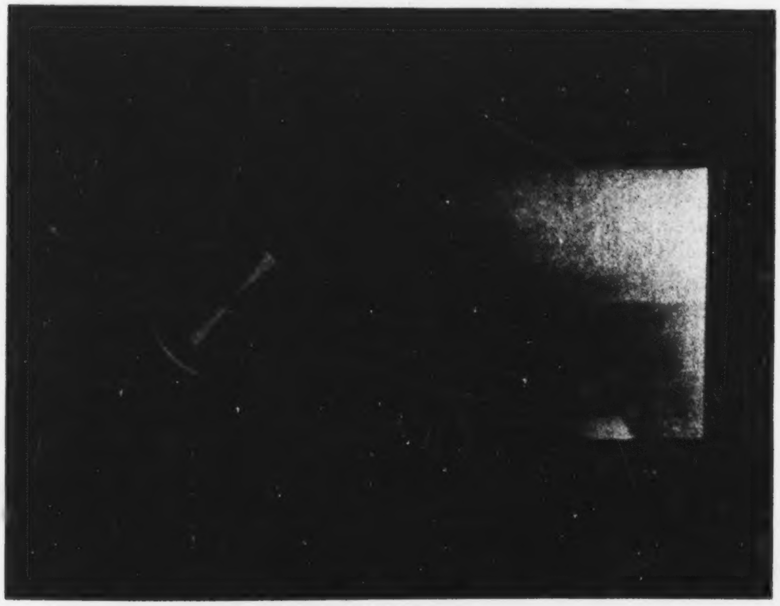


Fig. 4.4 A thermostat senses and measures heat.

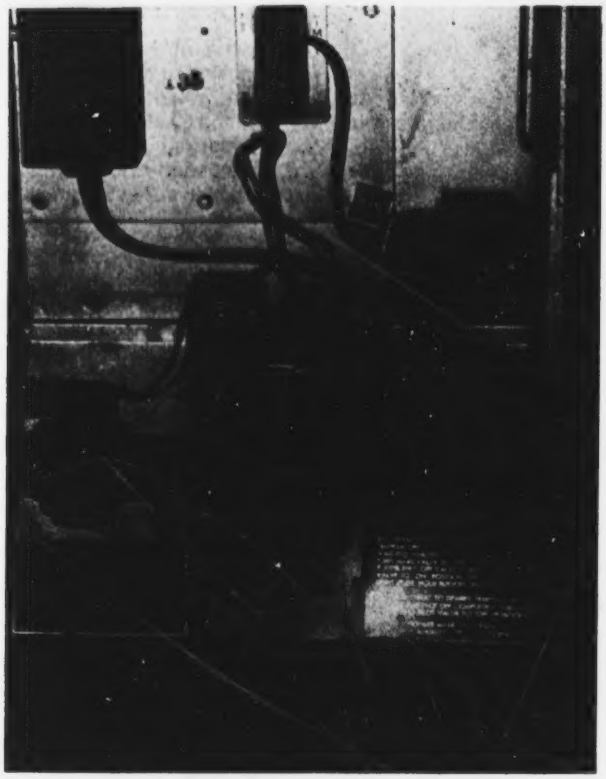


Fig. 4.5 A gas burner heater system is controlled by a thermostat.

shuts off automatically when it is full. This control system may be analyzed as follows:

1. The bowl is flushed and the water level drops in the flush tank.
2. This causes the float to drop (Fig. 4.6). The dropping of the float mechanically opens a hydraulic valve which releases water into the flush tank.
3. As water begins to rise in the tank, the float also rises. This in turn controls the amount of water entering the flush tank. Thus, the higher the float level, the lower the rate of water coming into the tank.
4. Finally, when the water level in the flush tank reaches its pre-set level, the float will also have risen to its maximum height. When the float reaches its maximum height (Fig. 4.7), it will automatically shut off the valve feeding water into the flush tank. This is accomplished through a set of mechanical levers.
5. The sequence will repeat itself whenever the toilet is flushed again.

The example above illustrates a hydro-mechanical control system using a simple float as the water-level measuring device and control system to either turn the water "ON" or "OFF" into the flush tank.

Therefore, an instrument may be defined as a measuring device; a control system is a device or series of devices that cause changes to occur. In the next section, we will examine why we need instruments and controls to operate a treatment plant.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 227.

6.0A Why are treatment plants being designed and constructed with sophisticated instrument-control systems?

6.0B What is an instrument?

6.0C What is a control?

4.01 Why Use Instruments and Controls?

So far we have discussed simple instrument and control systems; now let us examine why they are necessary and useful in operating a treatment plant. Since instruments basically measure values, let us examine why we need to use instruments in place of or to assist the opeator's sense of sight, hearing, touch, and smell. When we talk about measuring, we are taking into consideration the following related factors:

1. Accuracy of the measurement,
2. Repeatability of the measurement,
3. Sensitivity of the measurement, and
4. Permanence of the measurement.

4.010 Accuracy

Let us first examine the need for accuracy of measurement. In some instances it may be adequate to "eyeball" a linear measurement. An example of this would be roughly pacing off the width of a sand sludge drying bed. No great degree of accuracy is required or implied by this method. However, in another situation where we were installing expensive piping between pieces of machinery, we would want to increase the degree of accuracy by using a tape measure instead of pacing off the distance. Another situation requiring still greater accuracy would be measuring the diameter of a replacement pump shaft. Here a micrometer would be used for measuring the diameter of the shaft to the nearest thousandth of an inch (Fig. 4.8). In the last two examples, an operator's eyeball calibration is inadequate for the accuracy needed and specific instruments must be used.

In another example, an operator would be able to tell the passing of a day's time, let's say from sunset to sunset, and that would be accurate enough to mark the days off a calendar. However, if the operator wanted to operate the primary sludge pumps ten minutes each hour, a watch would be needed since the degree of accuracy required is greater than the ability to "guesstimate" the passing of time (Figs. 4.9 and 4.10).

So, we may conclude that depending upon the degree of measurement accuracy required, different types of instruments are needed to assist the operator perform different tasks. The accuracy of an instrument depends on the exactness of the measurements or how close the measurement is to the actual or true value.

4.011 Repeatability

For our use, repeatability may be defined as the ability to measure something again and obtain the same answer that resulted previously.

In our very first accuracy measurement example of pacing off the width of a sludge drying bed, our repeatability would probably not be too consistent. However, since the information would not be sought day after day and would not change, it would not be too important. However, in the situation where we were using a micrometer to measure the diameter of a pump shaft, repeatability would be very critical. We could not tolerate even a small discrepancy in repeatability.

Therefore, we may summarize that the repeatability of instruments is unquestionably superior to that of human sense measurements and that in many treatment plant operations using flow, temperature, pressure and other process variables, repeatability is absolutely essential for good operations.

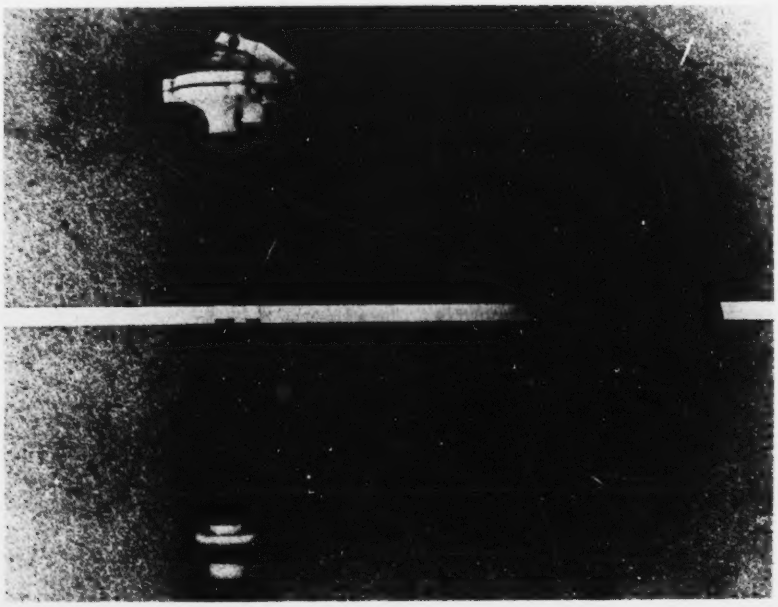


Fig. 4.6 Toilet bowl float in down position. Water will flow into toilet.

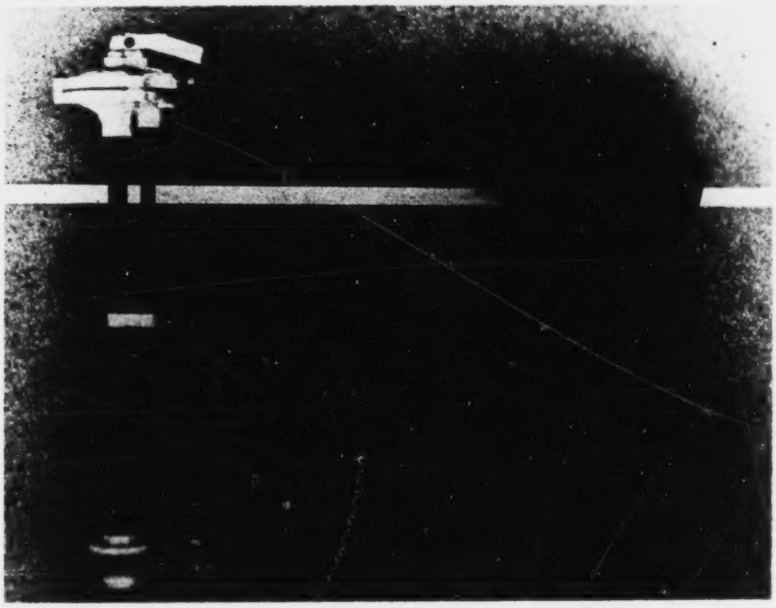


Fig. 4.7 Toilet bowl float in up position. Water will be shut off from flowing into toilet.

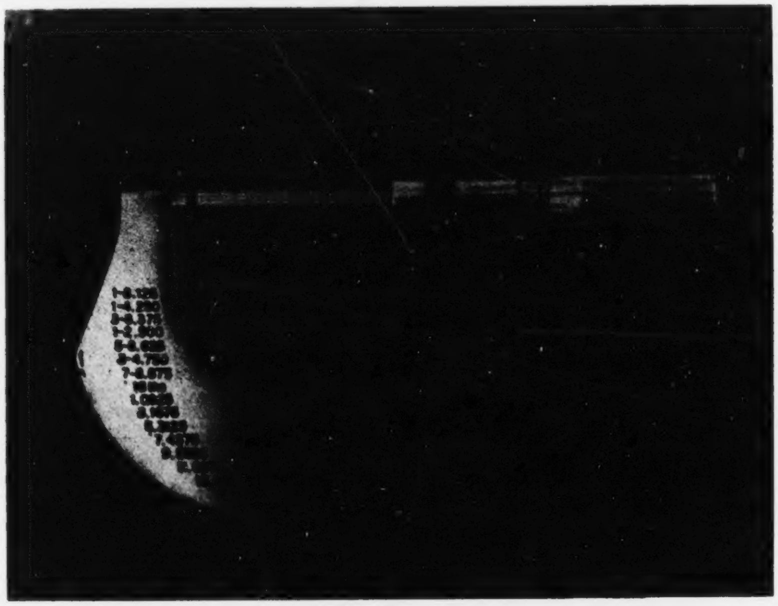


Fig. 4.8 A micrometer is used for close tolerance measurements.

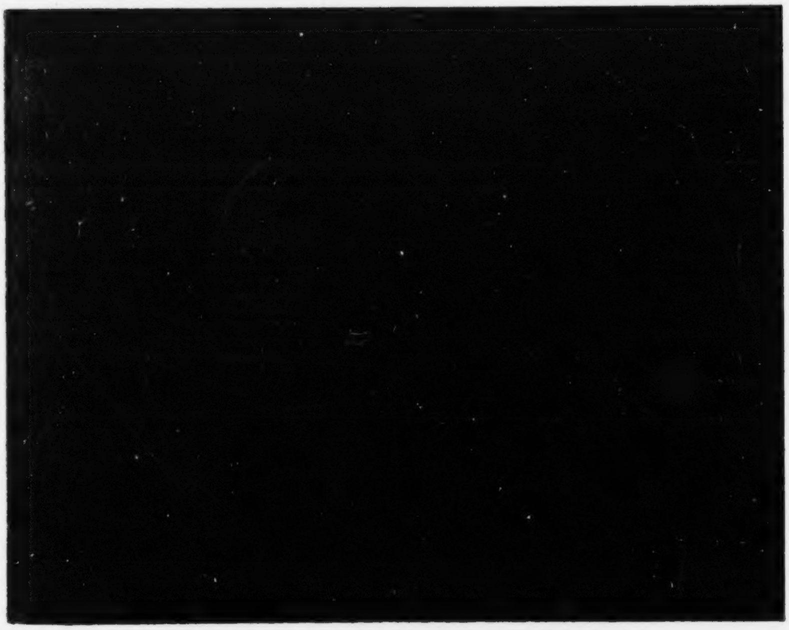


Fig. 4.9 A calendar is used to measure long lengths of time.

Fig. 4.10 A sundial is used to measure the approximate time of day. Sundials cannot measure time precisely.

4.012 Sensitivity

Sensitivity, for our use, may be defined as the ability to measure the smallest or largest value necessary.

As an example, the tape measurement would not be sensitive enough to measure to the nearest one thousandth of an inch. In another example, if we wanted to measure the gas pressure in an anaerobic sludge digester, we would want a pressure gage calibrated in inches or centimeters of water because 9 inches of water is only 0.32 psi. Therefore, a pressure gage calibrated in five-pounds-per-square-inch (5 psi or 0.4 kg/sq cm) increments would be too insensitive for our needs. In yet another example, a laboratory scale or balance (Fig. 4.11), calibrated in hundredths of a gram would be more sensitive than necessary and would not have the capacity to measure the weight of a chlorine cylinder in pounds. Therefore, the operator needs instruments that are properly sensitive to measure the smallest or largest unit (length, weight, time) increments necessary.

4.013 Permanence

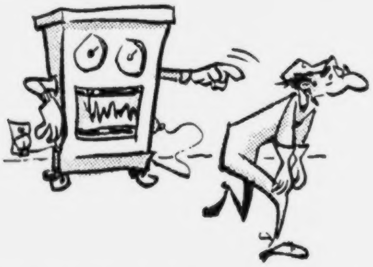
For the purposes of our use, permanence will be defined as maintaining accuracy, sensitivity, and repeatability over a long period of time. That is to say, a ruler or tape measure constructed out of paper would have little permanence. Conversely, a ruler constructed out of Invar metal would have very high permanence since it would be dimensionally stable.

In summary, we might say that good instruments exhibit a high degree of permanence, which is necessary for precise process control.

To this point we have discussed the ability of instruments to behave in an accurate, sensitive, repeatable and permanent manner in measuring numerous *PROCESS VARIABLES*[1] necessary for plant operations.

Instruments also measure variables which cannot be directly measured otherwise, for instance electricity. Human senses, for all practical purposes are incapable of measuring voltage and amperage (Fig. 4.12). Instruments also measure variables that would be unsafe to measure otherwise, such as extreme heat. Instruments that record also remove much of the drudgery associated with constant and repeated data taking. With the proper instruments, operators can measure chemical variables such as dissolved oxygen levels, pH (Fig. 4.13), chlorine residuals, and certain specific ions which could not otherwise be easily and/or quickly determined. Also, valuable time is saved by not having operators do jobs that could be done by instruments.

Therefore, we need and use instruments to accurately and quickly measure physical and chemical process variables that influence and/or control treatment plant processes. Human senses and "gut feelings" are no longer adequate to control a modern treatment plant.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 227.

4.0D Why do we need to use instruments in place of or to assist the operator's sense of sight, hearing, touch, and smell?

4.0E What is meant by the sensitivity of a measurement?

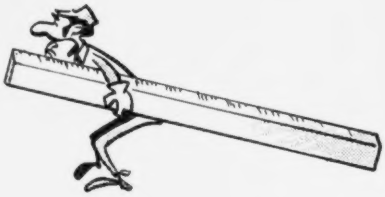
4.0F What is the difference between an instrument's accuracy and repeatability?

4.1 WHAT DO INSTRUMENTS MEASURE?

Thus far we have learned that instruments are some sort of measuring device. Also, that they are needed and used because they provide a more accurate, consistent, sensitive, and permanent means of monitoring (measuring) treatment processes than we can achieve by seeing, hearing, touching, or smelling.

Next we will discuss which values or variables are measured by instruments commonly used in wastewater treatment plants. We will define the meaning of the following measurements:

1. Temperature,
2. Pressure,
3. Flow,
4. Level,
5. Density,
6. Velocity, and
7. Analytical measurements (physical, chemical, or biological).



4.10 Temperature

Temperature may be defined as the degree of "hotness" or "coldness" of a substance from a given reference temperature. High temperatures are associated with a high level of molecular activity in a substance, and conversely, cold temperatures are associated with a low level of molecular activity. A good example of this would be water which, if heated enough, would turn into steam; if cooled enough, it would turn into ice.

Therefore, a thermometer (Fig. 4.14) or some other temperature-measuring device is used to measure the degree of hotness or coldness. With this information, we are able to control heat-sensitive processes within their optimum ranges (anaerobic sludge digestion) or be warned if safe temperature levels are exceeded (steam boiler).

4.11 Pressure

Pressure may be defined as a stress (push) uniformly exerted in all directions. For example, gas inside of a balloon exerts pressure uniformly to all parts of the balloon. A manometer (Fig. 4.15) or some other pressure-measuring

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[1] *Process Variable. A physical or chemical quantity which is usually measured and controlled.*

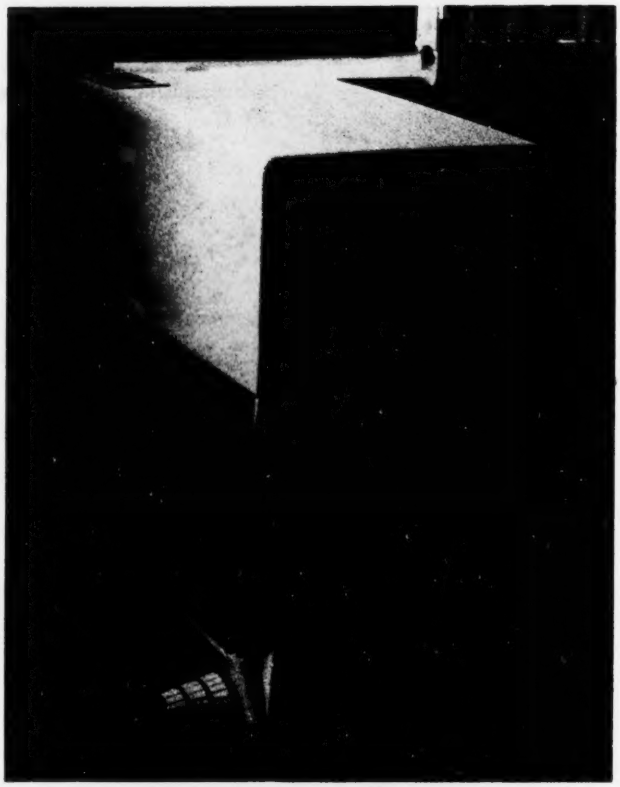

Fig. 4.11 A laboratory scale or balance is used to accurately measure small amounts of weights. Heavy quantities cannot be measured by lab scales.

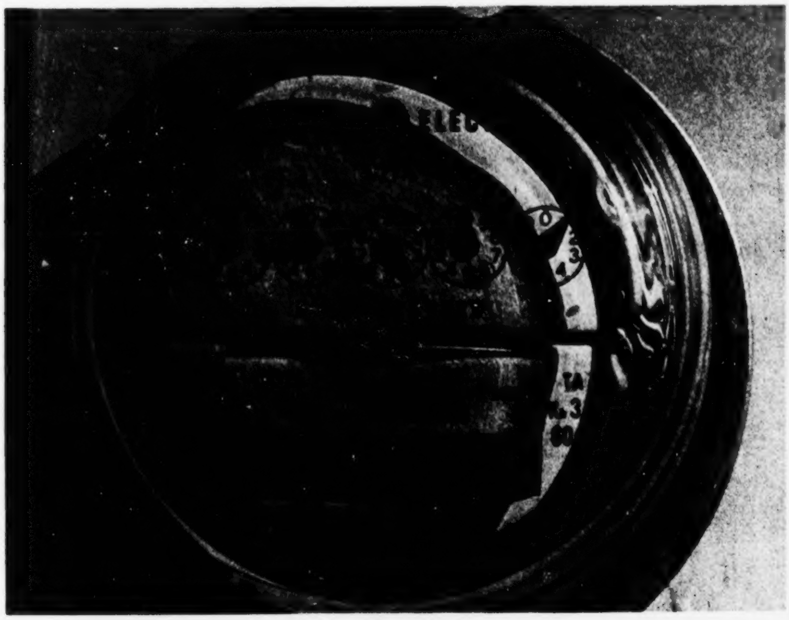

Fig. 4.12 A wattmeter is used to measure electrical energy. Human senses cannot measure electrical quantities.

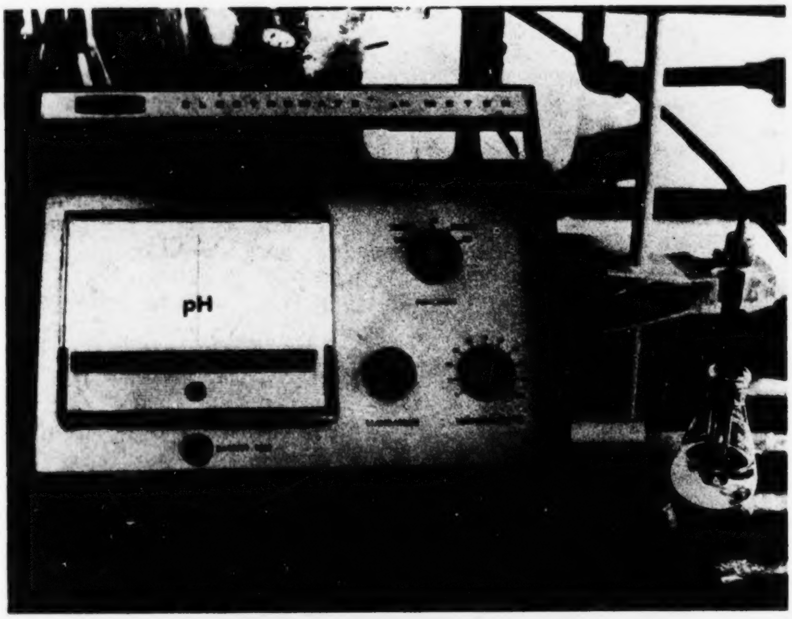

Fig. 4.13 A laboratory pH meter is used to measure a chemical quality of a liquid.

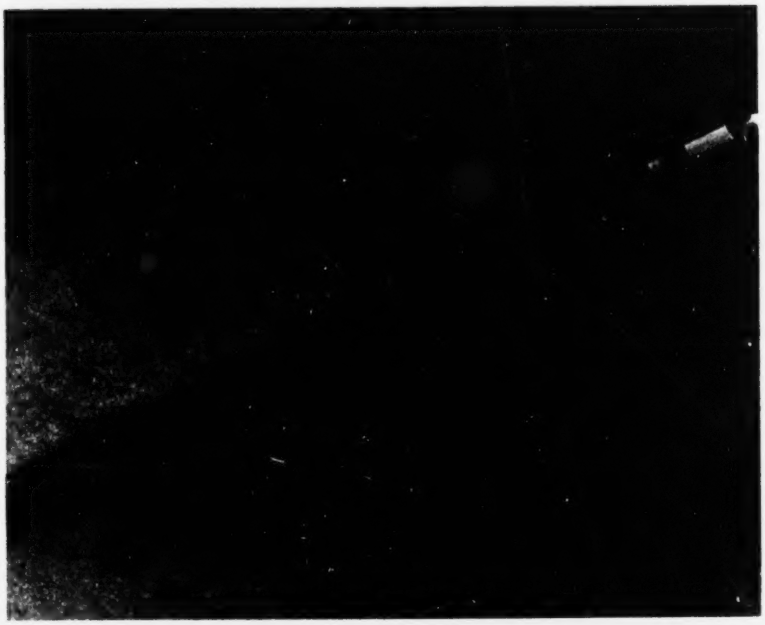

Fig. 4.14 A liquid-filled thermometer is used to measure temperature.

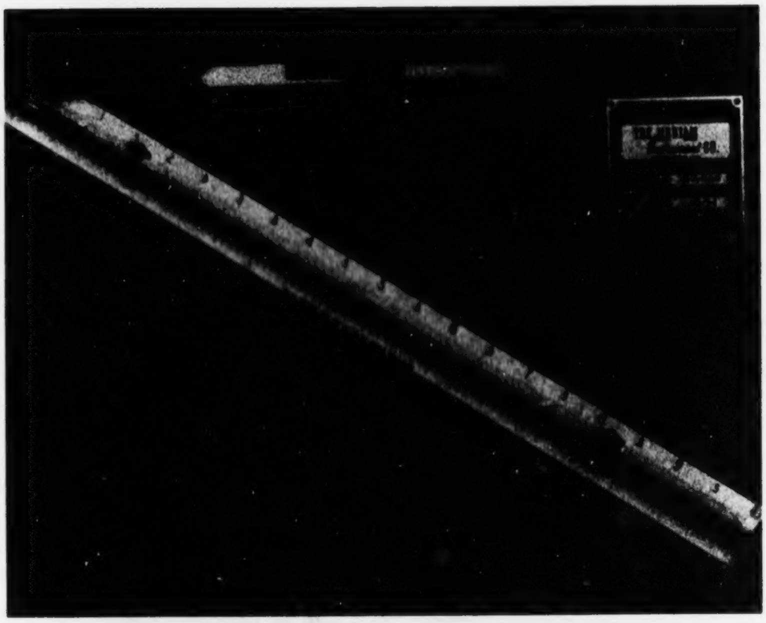

Fig. 4.15 An inclined manometer is used to measure relatively low pressures.

instrument is commonly used to measure the amount of pressure. Therefore, we are able to measure air pressure in order to limit the air pressure inside an air tank so that safe limits are not exceeded. Also, the suction and discharge pressures of a pump allow us to determine the total dynamic head (TDH) on a pump.

4.12 Flow

Flow may be defined in two ways, rate of flow and total flow or volume. Rate of flow may be defined as the volume of material passing a given point at any given *INSTANT OR TIME PERIOD.* Total flow may be defined as the amount or volume of flow passing a given point *WITHIN A SPECIFIC TIME PERIOD.*

For example, the return activated sludge (RAS) "flow rate" may be 200 GPM and the "total flow volume" would be 0.288 million gallons during one day.

$$
\begin{aligned}
\text{Flow volume, MG} &= \text{Flow rate, gal/min} \times \text{Time, day} \times 1440\ \text{min/day} \times \frac{1\ \text{Million}}{1{,}000{,}000} \\
&= 200\ \text{gal/min} \times 1\ \text{day} \times 1440\ \text{min/day} \times \frac{1\ \text{Million}}{1{,}000{,}000} \\
&= 0.288\ \text{MGal}
\end{aligned}
$$

4.13 Level

Level may be defined as a height measurement. Liquid surface levels can be measured directly by a floating ball or a measuring (dip) stick. For example, the amount of diesel fuel in a tank can be determined from the level of fuel. Sight tubes are used to measure liquid levels directly in a tank (Fig. 26.16). Levels also can be measured by indirect means such as electrical probes or by ultrasonic sound waves which bounce back like radar and induce a signal. Hydrostatic pressure in psi can be converted to a level or head by using the conversion factor 2.31 feet = 1 psi.

4.14 Density

Density may be defined as the weight of a material per unit volume. For example, the density of water is 62.4 lbs/cu ft. Liquid density may be measured by a hydrometer such as the type used to measure the amount of anti-freeze in a radiator. Primary sludge density may be measured by radioactive sensing cells.

4.15 Velocity (Speed)

Velocity may be defined as the length of travel in a given unit of time or: velocity = distance/time. An automobile speedometer (Fig. 4.17) measures velocity in terms of miles per hour. Another velocity or speed measurement is the RPM (revolutions per minute) made by an engine or pump (Fig. 4.18).

4.16 Analytical Measurements

Instruments also may be used to make analytical measurements. Chemical analytical or laboratory measurements are made for pH, dissolved oxygen, electrical conductivity, chlorine concentrations, and others. Physical measurements include turbidity and temperature while examples of a biological measurement are the tests to indicate the concentrations of coliform group bacteria or algae. Many laboratory measurements involve instruments using some sort of specialized probe and meter.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 227.

4.1A Why are instruments used instead of our human senses of seeing, hearing, touching, and smelling?

4.1B What do instruments measure?

4.1C How can flow be defined?

4.2 UNITS OF MEASUREMENT

Now that we understand what variables instruments measure, let us examine the common units of expression for these measurements.

1. *TEMPERATURE*

Fahrenheit: (English)	A unit of expression for temperature is the Fahrenheit scale, where the freezing of water is set at 32°F, and boiling of water is set at 212°F, covering a range of 180°F between the two points.
Celsius or Centigrade: (Metric)	Another common unit of temperature expression is the Celsius or Centigrade scale, which is commonly used in laboratory measurements and the metric system. The freezing of water is set at 0°C and boiling of water is set at 100°C, covering a range of 100°C between the two points.
Kelvin (Metric) & Rankine (English):	There are two other less commonly used temperature scales which incorporate the value of "Absolute Zero" where, theoretically, no molecular motion exists. The Kelvin scale sets the freezing point of water at +273°K and the boiling point at +373°K, giving a spread of 100° just like the Celsius scale. The Rankine scale sets the freezing point of water at +491.7°R and the boiling point at +671.7°R, giving a 180° spread between the points just like the Fahrenheit scale.

2. *PRESSURE*

Pounds per Square Inch:	The most common expression for pressure is pounds per square inch (psi). This means that each square inch of surface area is subjected to that many pounds of force. 1 psi = 0.070 kg/sq cm = 6895 Pascal = 6.9 kPa
Pounds per Square Foot:	Another pressure expression is given in pounds per square foot (psf). This means each square foot of surface area is subjected to that many pounds of force. 1 psf = 4.882 kg/sq m = 993 kPa

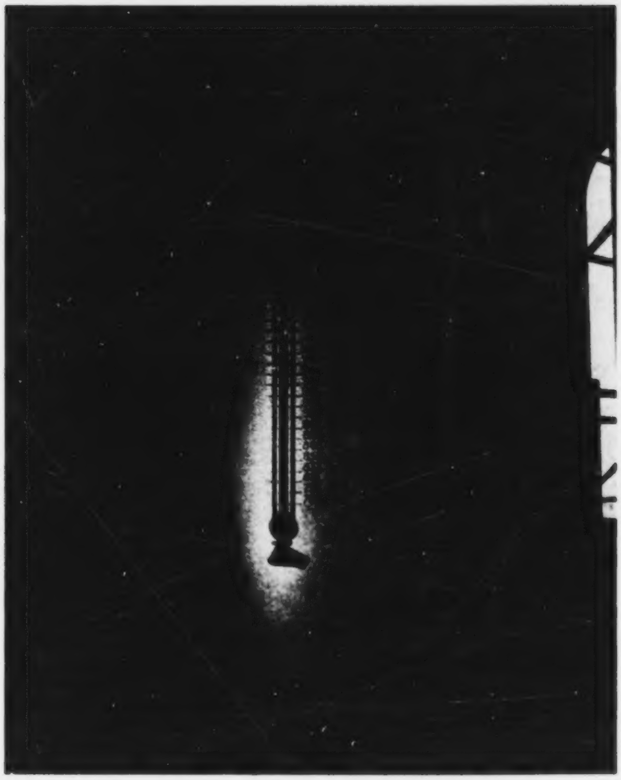

Fig. 4.16 Sight tubes are used to measure liquid levels directly in a tank.

Fig. 4.17 A speedometer is used to measure linear velocity.

0
100
200
300
400
500
REVOLUTIONS

Fig. 4.18 A tachometer is used to measure rotational velocity.

Inches or Feet of Head: Pressure may also be expressed in terms of inches of water, feet of water, or inches of mercury (Hg). Each of these expressions is related to the pressure that would be required to support a column of given liquid sometimes called "Head." Mathematically stated, since one cubic foot of fresh water weighs 62.4 pounds and there are 144 square inches per square foot, a one square inch column of water one foot or 12 inches high exerts a pressure of 0.433 lbs/sq in. For example, when the manometer connected to the dome of an anaerobic sludge digester reads 9 inches (23 cm) of water (H_2O), what the manometer is telling us is that the gas pressure inside the digester is exerting a force equivalent to that required to support a column of water (head) 9 inches (23 cm) high.

$$\begin{aligned}
\text{Pressure, lbs/sq in} &= \frac{\text{Weight, lbs}}{\text{Area, sq in}} \\
&= \frac{\text{Volume, cu ft} \times \text{Density, lbs/cu ft}}{\text{Area, sq in}} \\
&= \frac{\text{Area, sq in} \times \text{Height, in} \times \text{Density, lbs/cu ft}}{\text{Area, sq in} \times 1728 \text{ cu in/cu ft}} \\
&= \frac{1 \text{ sq in} \times 12 \text{ in} \times 62.4 \text{ lbs/cu ft}}{1 \text{ sq in} \times 1728 \text{ cu in/cu ft}} \\
&= \frac{0.433 \text{ lbs}}{1 \text{ sq in}} \\
&= 0.433 \text{ lbs/sq in}
\end{aligned}$$

Therefore, 0.433 psi = 1 ft head = 0.3 m
or 1 psi = 2.31 ft head = 0.7 m

Gage and Absolute Pressure: Pressure also is expressed as gage pressure or absolute pressure (Fig. 4.19). Gage pressure does not take into consideration the weight of the atmosphere above the earth; one atmosphere = 14.7 psi or 29.97 inches of mercury at sea level. Therefore, in converting to absolute pressure from gage pressure you must add barometric pressure (14.7 psi) to the gage pressure reading.

Gage Pressure, psi + Barometric Pressure, psi = Absolute Pressure, psi

For practical purposes, operators commonly use gage pressure because they want to know the *DIFFERENCES* in water pressure. Usually atmospheric (barometric) pressure does not influence work done by operators. Absolute pressure is used when working with gases and calculating changes resulting from changes in the pressure, temperature, and/or volume of a gas.

Vacuum Pressure: So far we have been discussing positive pressures. Whenever a pressure falls below atmospheric pressure, a negative pressure is exerted which is called a vacuum. Consequently, when an open-tube manometer on a vacuum filter or vacuum receiver reads 20 inches (51 cm) of mercury (Hg), this is equivalent to a negative or minus gage pressure of 9.76 lbs/sq in (0.69 kg/sq cm). Mercury has a density 13.55 times heavier than water.

$$\begin{aligned}
\text{Pressure, lbs/sq in} &= \frac{\text{Density, lbs/cu ft} \times \text{Head, ft}}{144 \text{ sq in/sq ft}} \\
&= \frac{13.55 \times 62.4 \text{ lbs/cu ft} \times 20 \text{ in}}{144 \text{ sq in/sq ft} \times 12 \text{ in/ft}} \\
&= 9.79 \text{ lbs/sq in } (0.69 \text{ kg/sq cm})
\end{aligned}$$

$$\begin{aligned}
\text{Absolute Pressure, psi} &= \text{Atmos. Press., psi} + \text{Gage Press., psi} \\
&= 14.7 \text{ psi} + (-9.8 \text{ psi})^{*} \\
&= 4.9 \text{ psi}
\end{aligned}$$

* — means a vacuum or negative pressure.

Note that the units of pressure are the same for liquids and gases.

3. *FLOW RATE*

Liquids: Flow rates for liquids are usually expressed as volume per unit time. The most common units are gallons per minute, gpm (gal/min), cubic feet per second (cfs or cu ft/sec) and million gallons per day (MGD). In each of the above cases, a given volume of liquid moves past a given point during a unit of time.

Gases: Flow rates for gases are usually expressed as cubic feet per minute (cfm or cu ft/min), cubic feet per hour (cfh or cu ft/hr), and cubic feet per day (cfd or cu ft/day). Many instruments are calibrated in SCFM where the S refers to **S**tandard conditions of temperature, pressure and humidity. The same flow rate definitions apply to gases as for liquids.

Solids: Flow rates for solids are commonly expressed as pounds per hour (pph or lbs/hr), pounds per day (ppd or lbs/day) or tons per hour. They also may be expressed in volumetric terms such as cubic feet per day (cfd or cu ft/day) or cubic yards per day (cyd or cu yd/day). Therefore, we may conclude that flow may be measured in terms of volume or weight.

4. *LEVEL*

The units for expression for level are usually expressed in terms of inches or feet (cm or m). However, in the laboratory, the metric units of measurement are used such as millimeter (mm), centimeter (cm), or meter (m).

5. *DENSITY*

Percent Solids: Although we have defined density as weight per unit volume, instrumentation in a treatment plant can be calibrated to read in percent solids for sludges.

Specific Gravity: The density of liquids is measured by a hydrometer expressing units of specific gravity (which is the ratio of specific gravity of a liquid to the specific gravity of water, which is one).

6. *VELOCITY*

Velocity measurements in a treatment plant are usually expressed in terms of feet per second (fps or ft/sec); feet per minute (fpm or ft/min); or for rotational velocities, in revolutions per minute (rpm or rev/min).

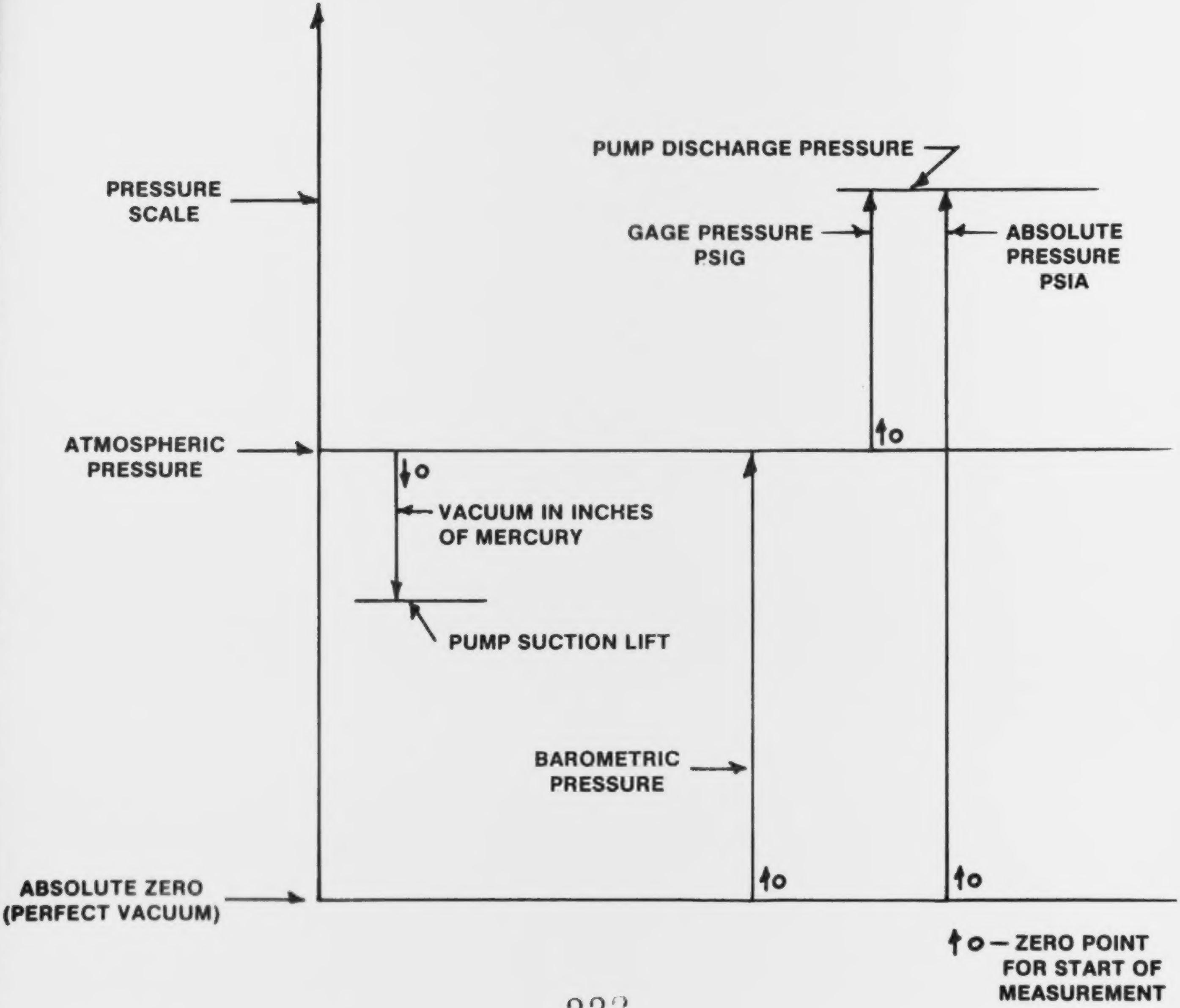
PUMP DISCHARGE PRESSURE
PRESSURE SCALE
GAGE PRESSURE PSIG
ABSOLUTE PRESSURE PSIA
0
ATMOSPHERIC PRESSURE
0
VACUUM IN INCHES OF MERCURY
PUMP SUCTION LIFT
BAROMETRIC PRESSURE
0
0
ABSOLUTE ZERO (PERFECT VACUUM)
0 — ZERO POINT FOR START OF MEASUREMENT

Fig. 4.19 Measurement of pressures

7. *ANALYTICAL MEASUREMENTS*

Analytical measuring instruments are very specific in what and how they measure. Some of the units of expression for the more common analytical instruments found in a treatment plant laboratory are discussed in the next paragraphs.

pH meters read in units of pH; dissolved oxygen meters read in milligrams per liter (mg/*L*); and electrical conductivity meters usually read in mhos which are equal to 1/ohm.

There are also other more sophisticated laboratory instruments such as Total Organic Carbon Analysers, Gas Chromatographs, Infrared Spectrophotometers, Atomic Absorption Units, and others which are way beyond the capability of this section, and therefore will not be discussed further. Table 4.1 summarizes the common units of measurement.

TOTAL ORGANIC CARBON ANALYSERS
GAS CHROMATOGRAPHS
INFRARED SPECTROPHOTOMETERS
AND OTHERS
ATOMIC ABSORPTION UNITS

QUESTION

Write your answer in a notebook and then compare your answer with the one on page 227.

4.2A Complete the following table by writing both the English and Metric units for the following variables measured by instruments or sensors.

Measurement	English	Metric
1. Temperature		
2. Pressure		
3. Flow		
4. Level		
5. Density		
6. Velocity		

END OF LESSON 1 OF 4 LESSONS ON INSTRUMENTATION

Please answer the discussion and review questions before continuing with Lesson 2.

TABLE 4.1 UNITS OF MEASUREMENTS AND ABBREVIATIONS

Measurement	**Common Units of Measurement and Abbreviations**	
	ENGLISH	
1. Temperature	a) Fahrenheit:	
	Freezing Point of Water = +32°F	
	Boiling Point of Water = +212°F	
	b) Rankine:	
	Freezing Point of Water = +491.7°R	
	Boiling Point of Water = +671.7°R	
	METRIC	
	c) Celsius or Centigrade:	
	Freezing Point of Water = 0°C	
	Boiling Point of Water = +100°C	
	d) Kelvin:	
	Freezing Point of Water = +273°K	
	Boiling Point of Water = +373°K	
	ENGLISH	*METRIC*
2. Pressure	a) Pounds per square inch = psi or lb/in^2	kg/sq cm
	b) Pounds per square foot = psf or lb/ft^2	kg/sq m
	c) Inches of water = inches H_2O	mm H_2O
	d) Feet of water = feet H_2O	m H_2O
	e) Inches of Mercury = inches Hg	mm Hg
	f) Absolute pressure = psia	kg/sq cm
	g) Gage pressure = psig	kg/sq cm
3. Flow	a) Liquids (volume)	
	gallons per minute = gpm or gal/min	*L*/sec or cu m/sec
	gallons per hour = gph or gal/hr	*L*/sec
	cubic feet per second = cfs or ft^3/sec	cu m/sec
	million gallons per day = MGD	cu m/day
	b) Gases (volume)	
	cubic feet per minute = cfm or ft^3/sec	*L*/sec or cu m/sec
	cubic feet per hour = cfh or ft^3/hr	*L*/sec
	cubic feet per day = cfd or ft^3/day	*L*/sec
	c) Solids or Liquids (weight)	
	pound per minute = ppmin or lbs/min	gm/sec
	pound per hour = pphr or lbs/hr	gm/sec or kg/hr
	pound per day = ppd or lbs/day	kg/day
	d) Solids (volume)	
	Cubic feet per day = cfd or ft^3/day	cu m/day
	Cubic yard per day = cyd or yd^3/day	cu m/day
4. Level	a) inches = in	mm
	b) feet = ft	m
5. Density	a) Percent solids = %	
	b) Specific Gravity = Sp.Gr.	
	c) Parts per Million = ppm	
6. Velocity	a) Linear:	
	feet per second = fps or ft/sec	m/sec
	feet per minute = fpm or ft/min	m/min or mm/sec
	b) Rotational:	
	Revolutions per minute = RPM	RPM
7. Analytical	a) Hydrogen Ion Concentration = pH	pH
	b) Dissolved Oxygen = ppm or mg/*L*	mg/*L*
	c) Electrical Conductivity = mhos	mhos
8. Energy or Work	foot – pounds	joule
9. Power	foot – pounds/sec or horsepower	joule/sec or watt

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 4 Lessons)

Chapter 4. INSTRUMENTATION

At the end of each lesson in this chapter you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson.

Write the answers to these questions in your notebook.

1. Why do treatment plants have instruments and controls?
2. Why are some instruments more accurate, consistent and sensitive than human senses?
3. How would you measure the depth of water in a wet well?

CHAPTER 4. INSTRUMENTATION

(Lesson 2 of 4 Lessons)

4.3 HOW DO INSTRUMENTS (SENSORS) MEASURE?

Now that we are familiar with the units of measurements expressed by instruments, let's examine in a simple manner how treatment plant instruments function. The operator must be reasonably familiar with what makes instruments "tick" in order to determine if an instrument or control is operating properly or if a problem exists.

Due to a wide and ever-expanding variety of instrumentation and control systems, only the most common types that an operator might work with will be discussed in this section.

1. *TEMPERATURE*

Temperature measurements involve the transfer of heat or cold between the material whose temperature is being measured and the temperature sensing instrument. Let's examine the workings of several of the more common temperature-sensing instruments.

A. *LIQUID-FILLED THERMOMETER*

Everyone is familiar with this device, a sealed, hollow glass tube filled with liquid. Let us examine how a mercury filled thermometer works. Mercury expands when heated. Consequently, when heat is applied to or removed from a mercury thermometer, the volume of mercury expands or contracts at a much greater rate than the glass tube containing the mercury. This forces the mercury to move up or down a precise amount for each degree change in temperature. The amount of mercury movement and sensitivity of the thermometer depends on the size (diameter) of the bore of the glass tube. The outside of the glass tube is equally subdivided to correspond to the change in mercury volume as a function of the change in temperature.

All liquid-filled thermometers work on the stated basic principle that the liquid inside the thermometer expands at a greater rate than the glass tube surrounding it and the distance of movement in the tube is calibrated in degrees. A variation of this principle uses a bulb containing the temperature sensitive liquid which is connected to a capillary tube in which the expanding liquid travels up or down in the tube (Fig. 4.20). The capillary tube is connected to a specially shaped hollow tube which bends as the liquid from the capillary tube enters or leaves it. The free end of the hollow tube is connected to a mechanical linkage which is calibrated to indicate the change in temperature.

Still another variation of the above principle uses a gas as the expanding media in the bulb instead of the liquid; otherwise, they are quite similar in operation and principle.

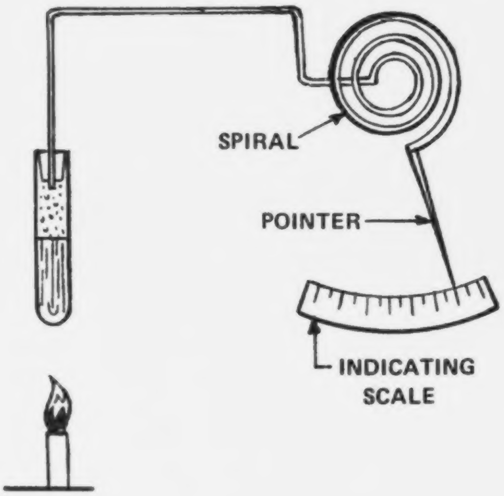

Fig. 4.20 An expanding or contracting fluid may be used to measure temperature.

B. *BIMETALLIC THERMOMETER*

In a bimetallic-type of temperature measuring device, two metals with different rates of thermal expansion are fused together. When heat is applied to the bimetallic element which has one end fixed, the metal with the greater coefficient of thermal expansion expands a greater amount and causes the bimetallic element to bend or flex. The amount of bending is called "flexivity." The bending end of the bimetallic element is mechanically connected to a pointer which indicates the temperature change in degrees.

C. *THERMOCOUPLE*

Simply stated, a thermocouple is a device consisting of two different types of metallic wires joined together, which when heated produce an electrical voltage (electromotive force or EMF). The voltage produced is proportional to the amount of heat applied at the junction of the two different metals and can be read by a millivoltmeter which is calibrated so as to convert the change in voltage to the corresponding change in temperature (see Fig. 4.21).

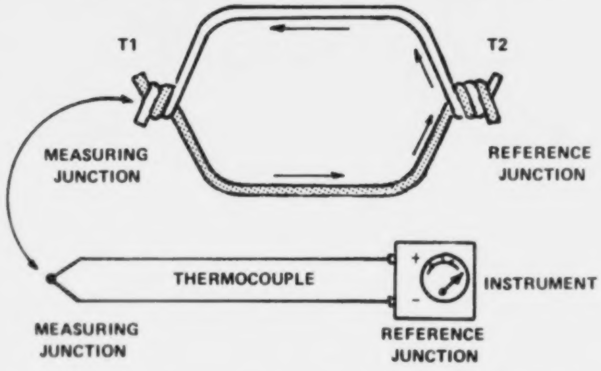

Fig. 4.21 A thermocouple is used to measure temperature.

So far we have examined several ways of sensing temperature. Each method has its most suitable application based on such factors as temperature range, accuracy, sensitivity, costs, durability, and corrosion resistance.

2. *PRESSURE*

We defined pressure as the amount of force applied to a unit area. For our purpose, we will be primarily concerned with gage pressure which is the amount of pressure shown on the pressure-measuring instrument. Let us examine how several common pressure-sensing (measuring) instruments function.

A. *MANOMETER*

A manometer is a liquid-filled glass tube device (Fig. 4.22). The liquid is raised or lowered by the pressure exerted by the fluid (liquid or gas) being measured. Different ranges of pressure may be measured by changing the liquid in the manometer to one of a lower or higher specific gravity; water and mercury are the most common liquids used. The sensitivity of a manometer also may be increased by inclining (sloping) the measuring leg of the manometer rather than using a vertical measuring leg.

The applied pressure on one tube of a U-tube manometer (the other tube is open to atmospheric pressure) is equal to the total vertical height of the liquid column times the density of the liquid.

Pressure, lbs/sq ft = Height, ft × Density, lbs/cu ft

or Pressure, lbs/sq in = Height, in × Density, lbs/cu in

When pressure is applied to both tubes of a U-tube manometer, the differential pressure may be read directly without regard to the actual pressures involved. Again, in this case, the differential pressure is equal to the height of the liquid column times the density of the manometer liquid (Fig. 26.23).

Differential Pressure, psi = P_2, lbs/sq in − P_1, lbs/sq in

= Height, in × Density, lbs/cu in

When reading the U-tube manometer, the value of h is the difference in height between the top of the liquid of the left and right legs of the U-tube. To eliminate this step, a well manometer can be used. In this type of manometer, the area of the well is large enough in comparison to the bore of the manometer so that the applied pressure may be read directly (Fig. 4.24). Also, the scale of the manometer may be made (calibrated) to compensate for the drawdown of the fluid in the large well.

Pressure, psi = Height, in × Density, lbs/cu in

B. *PRESSURE GAGES*

The most common types of pressure-measuring instruments use some type of element that undergoes elastic deformation (bends or flexes and then returns to its original shape or location). Both low and high pressures may be measured with gages employing this principle.

BOURDON TUBE (Fig. 4.25)

The Bourdon Tube is one of the most common pressure element devices employing the elastic deformation principle. The element consists of a thin metal tube, elliptical in cross section, formed into a "C" shape; one end of the "C" is rigidly attached to a socket where the pressure to be measured is applied, the other free end is mechanically linked to a gage movement which is calibrated to indicate the desired pressure units. When pressure is applied to the "C" shaped tube, it begins to straighten (unwind) out (just like a New Year's Eve party blower). The amount of movement caused by the straightening out process is not linear; it moves more per unit pressure at first and then decreases in the amount of movement as the pressure increases. Therefore, only a small part of the possible movement is used to measure pressure. A 0 to 60 psi (4.22 kg/sq cm) element will move only 0.25 of an inch (0.64 cm).

In elastic deformation elements, pressures in excess of that designed for a particular unit will deform the element and it will not return to zero (or original shape), thus ruining the gage. Lower pressure elements are usually made of copper alloys; some of the higher pressure elements are made of carbon steels.

DIAPHRAGM OR BELLOWS ELEMENTS

Another type of elastic deformation pressure element is the diaphragm or the bellows (Fig. 4.26). In both of these systems, the applied pressure deforms (moves) the diaphragm or the bellows a small amount. The amount of movement is mechanically linked to a gage movement for expression of the applied pressure. Diaphragm- and bellows-type pressure elements are commonly used for low pressures such as 0 to 10 inches (25.4 cm) of water. Although the bellows are

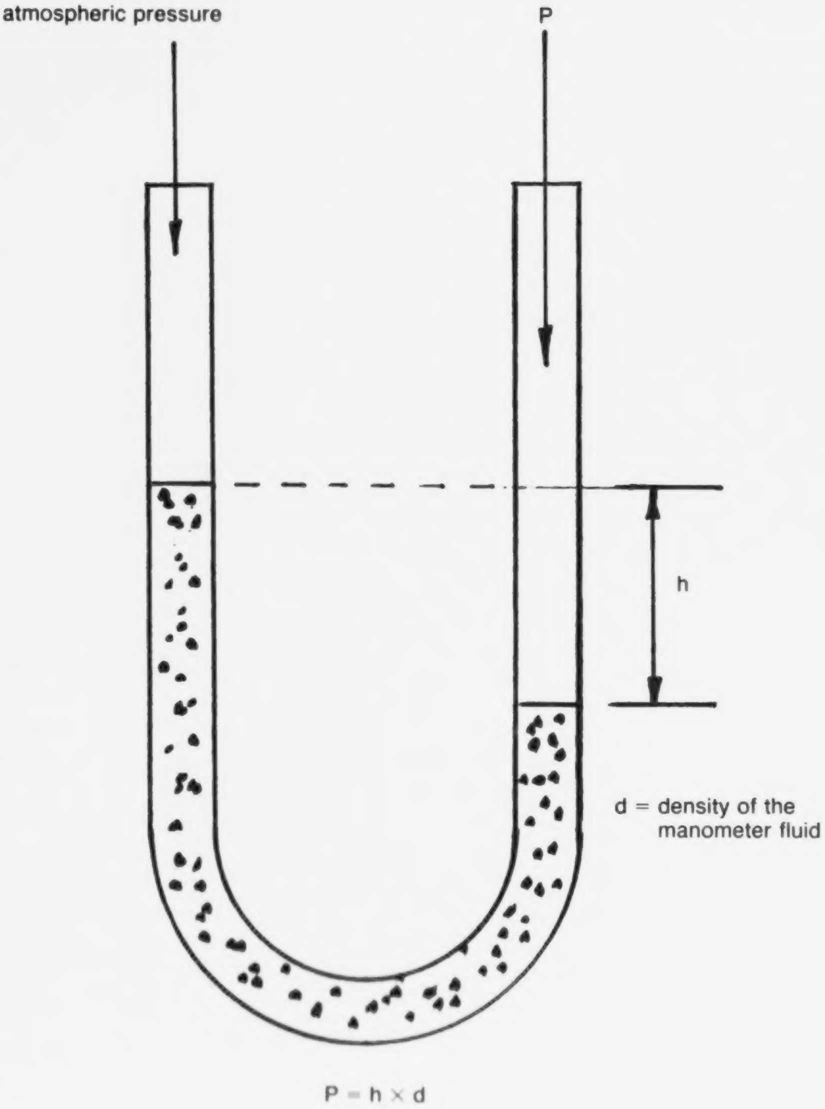
atmospheric pressure
P
h
d = density of the manometer fluid
P = h × d

Fig. 4.22 A simple U-tube manometer used to measure pressure.

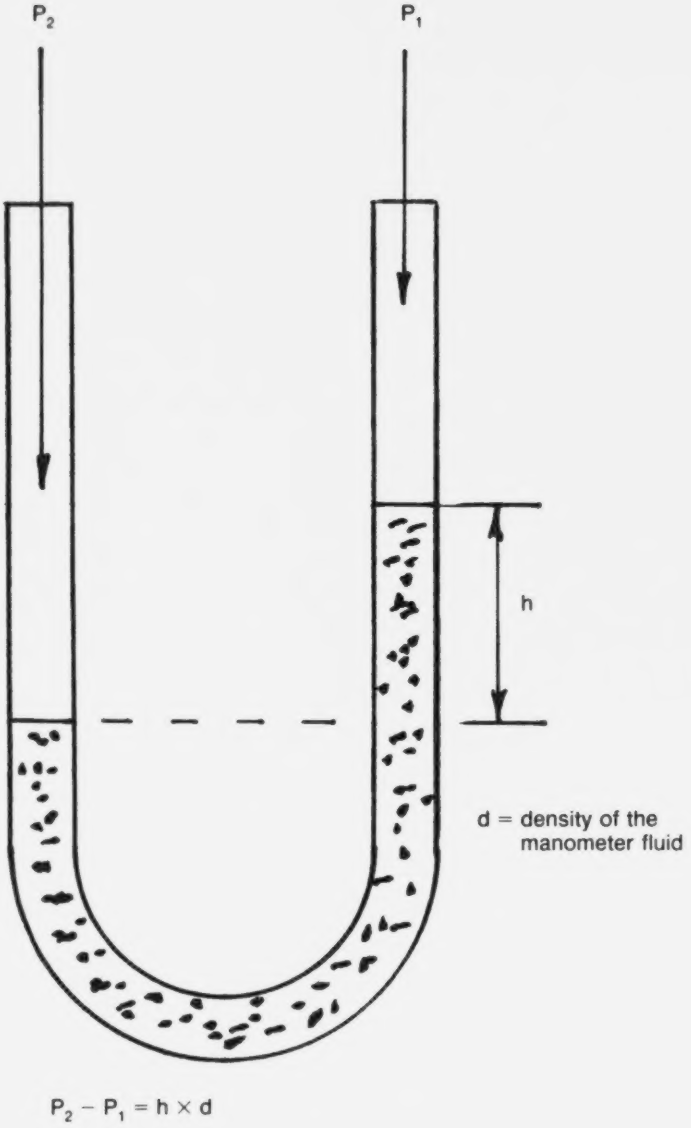
P₂
P₁
h
d = density of the manometer fluid
P₂ − P₁ = h × d

Fig. 4.23 A U-tube manometer used to measure a differential pressure.

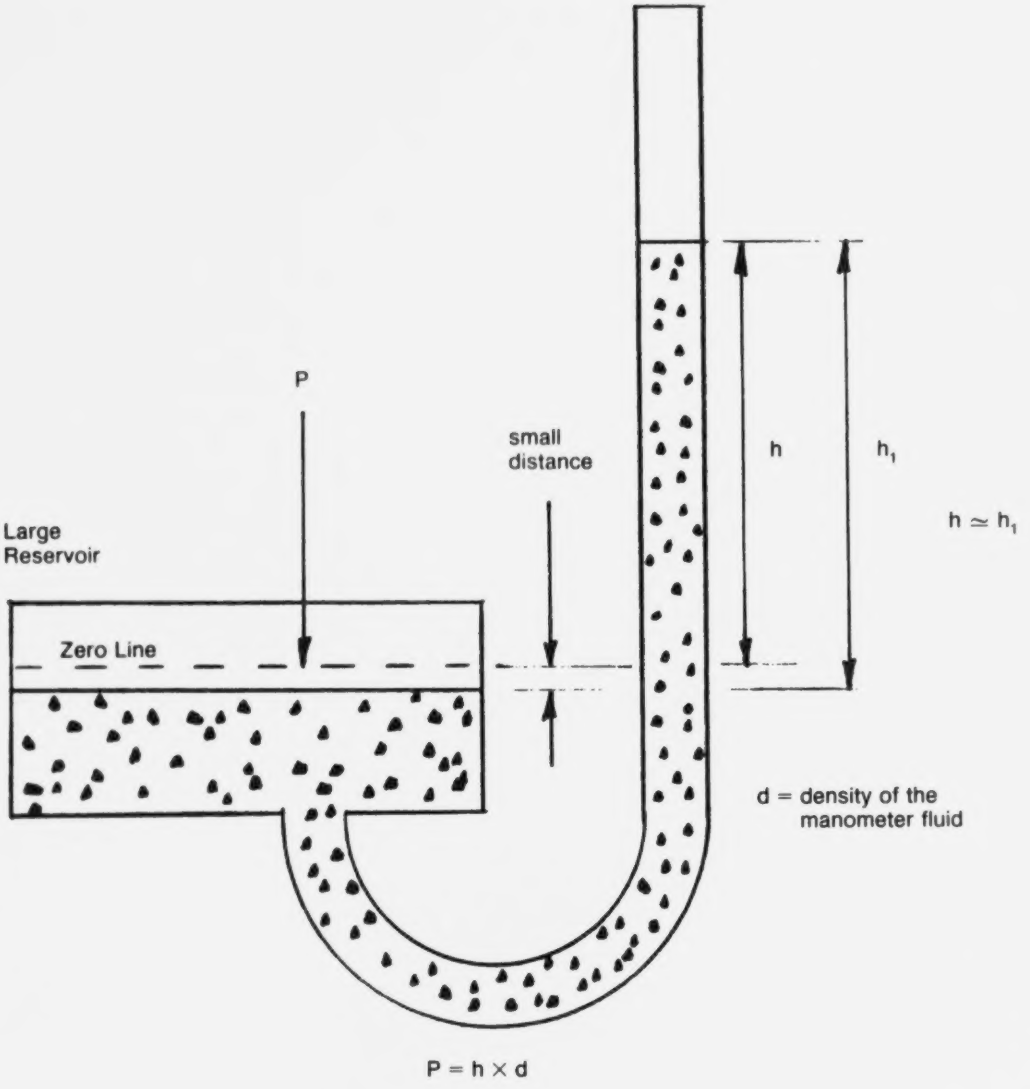
P
small
distance
Large
Reservoir
Zero Line
h
h_1
$h \simeq h_1$
d = density of the
manometer fluid
$P = h \times d$

Fig. 4.24 A wet-well manometer used to measure pressure

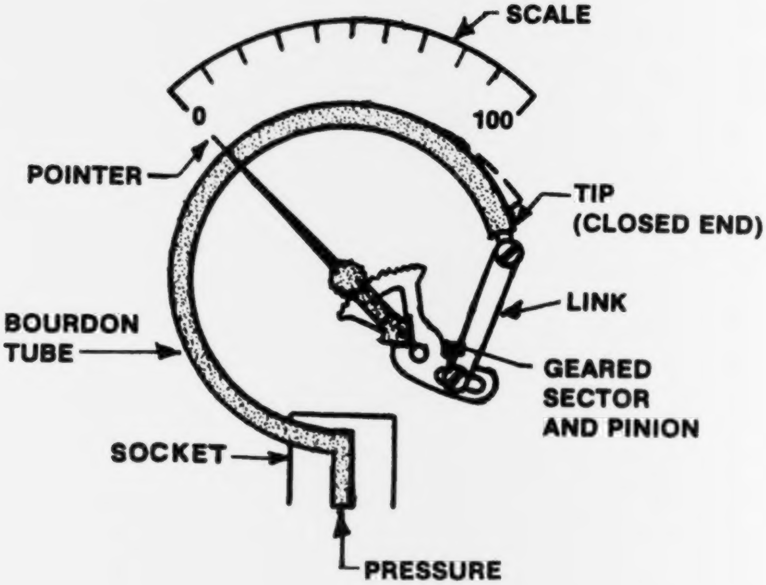
SCALE
0
100
POINTER
TIP
(CLOSED END)
LINK
BOURDON
TUBE
GEARED
SECTOR
AND PINION
SOCKET
PRESSURE

Fig. 4.25 A Bourdon tube is used to measure pressure.

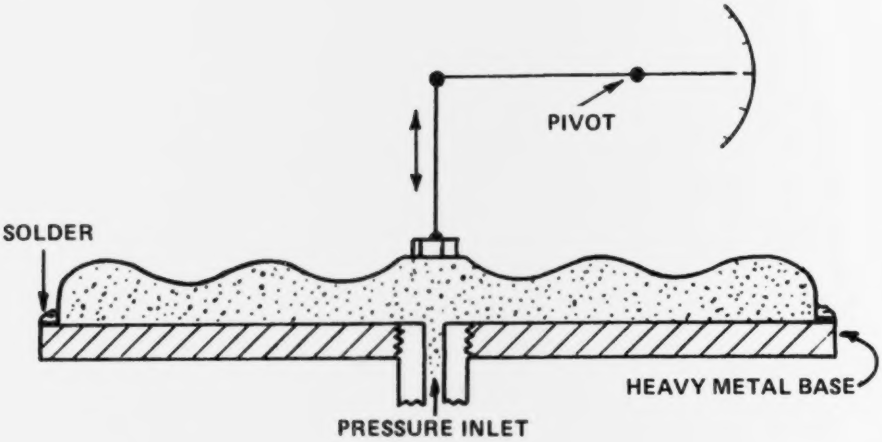
PIVOT
SOLDER
HEAVY METAL BASE
PRESSURE INLET

Fig. 4.26 A metal diaphragm is used to measure pressure.

usually constructed from metals, the diaphragms can be made from different materials depending upon the application, such as the need for a corrosion-resistant material.

3. *FLOW*

There are several different types of instruments used to measure flow in either pipes or open channels. All of these instruments attempt to measure the flow velocity and area.

Flow or Quantity = Area × Velocity
= AV
or Q, cu ft/sec = Area, sq ft × Velocity, ft/sec

Many flow meters estimate the velocity by measuring the difference in pressure as the fluid flows through a restriction such as an orifice or a Venturi. Because flow measurements are so important to the operation of a wastewater treatment plant, this topic was covered in Chapter 15, "Maintenance," Section 15.4, "Flow Measurements," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS.* Flow measurements are used by operators to determine what and how many units of treatment plant facilities must be on-line at any one time. Daily flows are used to calculate plant loadings and plant efficiencies.

4. *LEVEL*

The simplest and most direct means of measuring levels for clean liquids is the sight tube. However, it may not be practical to install a sight tube in many applications, therefore, other level-measuring devices are employed.

A. *FLOAT SYSTEM*

A float tied to a cable or rod is one of the most commonly used level-measuring devices. The float rests on the surface of the liquid being measured and rises or falls with the liquid surface. In another system, the float is connected to a mechanical linkage and the buoyancy of the float is used to signal the liquid level (Fig. 4.27).

B. *ELECTRIC PROBE*

Electric probes are commonly used to measure a single level, such as a high- or low-level alarm. In the case of the high-level alarms, the rising liquid allows an electrical current to flow between two contacts in the probe. When the current flows, a relay is tripped which energizes a secondary signal. In the low-level situation, the reverse is true. When the liquid drops below the probe, the electrical current stops flowing and causes another relay to activate another secondary signal.

C. *CAPACITANCE PROBE*

Similar to electric probes, capacitance probes are also used. In this system, the capacitance (an electrical term used to measure the capability of holding an electrical charge) changes when the liquid is in or out of contact with the probe, which in turn actuates a relay, which can trip a secondary device or send a signal.

D. *ULTRASONIC SOUND*

Another type of probe is the ultrasonic probe. This device uses a miniature transmitter and receiver at the end of the probe. The signal sent by the transmitter to the receiver changes when the probe is in or out of the liquid, which in turn activates a relay system to perform the necessary function.

The ultrasonic system also may be used to constantly monitor the process level. In this system the transmitter and receiver are mounted on top of the tank and the time interval it takes for a transmitted ultrasonic sound signal to be reflected off the liquid surface or solid being measured and bounced back to the receiver is electronically translated into a level measurement (Fig. 4.28).

E. *DIAPHRAGM BOX*

The diaphragm-box level indicator uses a sealed box containing a flexible diaphragm exposed to the liquid being measured. The hydrostatic pressure exerted upon the submerged diaphragm causes the volume of the sealed box to fluctuate with the changes in liquid level; this change in air volume (pressure) is transmitted through a tube to a pressure gage calibrated to read in inches or feet (centimeters or meters).

F. *BUBBLER TUBE*

The bubbler tube uses air pressure to measure liquid levels. This system is based on the required air pressure necessary to overcome the hydrostatic pressure at the bottom of a container. In practice, a tube is vertically lowered into a container and the air pressure increased to the point where water is blown out of the tube and air bubbles begin to flow out. The *PRESSURE REQUIRED* to force air out of the tube *VARIES WITH THE LIQUID LEVEL* and this relationship is converted to level measurement. This particular system is applicable only to liquid surfaces open to the atmosphere and cannot be used for sealed containers (Fig. 4.29).

5. *DENSITY*

Process density measurements in a treatment plant are usually made for primary sludge or return activated sludge concentrations in a pipeline. Almost all of the measuring instruments use the principle of sending a signal across the sludge flow path and relating the density of the sludge to the strength of the signal received. This is based on the fact that the greater the density of the sludge, the greater the attentution (reduction) in signal strength. The signal source may be a radioactive cell, an ultrasonic sound wave, or a light beam. The reduction in signal strength is usually calibrated against flows with known solids concentrations and the instruments are adjusted to read accordingly.

6. *VELOCITY*

Usually the only velocity measurement made in a treatment plant is rotational velocity or RPM. This is commonly accomplished by some type of tachometer.

An electro-mechanical tachometer uses a flexible cable or some other device to pick up the rotating movement. The tachometer may use a gear box to increase or decrease the rotating motion. This rotating movement is used to drive a small electrical generator whose electrical output is calibrated in RPM (revolutions per minute). The faster the RPM the higher the electrical output and visa versa.

Another tachometer system uses a strobe light. The frequency of the strobe light is adjusted until the motion of the equipment whose rotation is being measured appears to stop or stand still. This frequency is then converted into the equivalent RPM.

An electrical tachometer consists of a transducer which converts rotational speed into an electrical signal coupled to an indicator or recorder. One type of transducer is a magnetic pickup head which produces electric pulses each time a tooth of a rotating gear passes. The pulses can be digitally counted and displayed in terms of revolutions per minute.

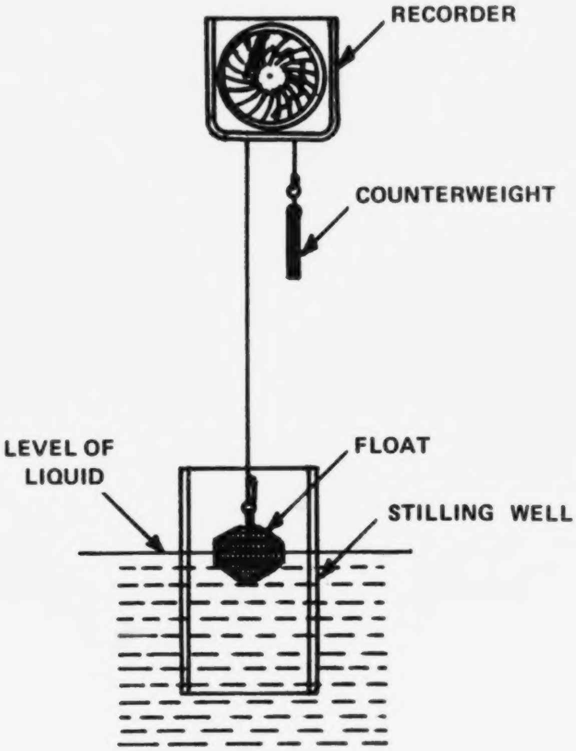
RECORDER
COUNTERWEIGHT
LEVEL OF LIQUID
FLOAT
STILLING WELL

Fig. 4.27 A float is used to measure liquid level.

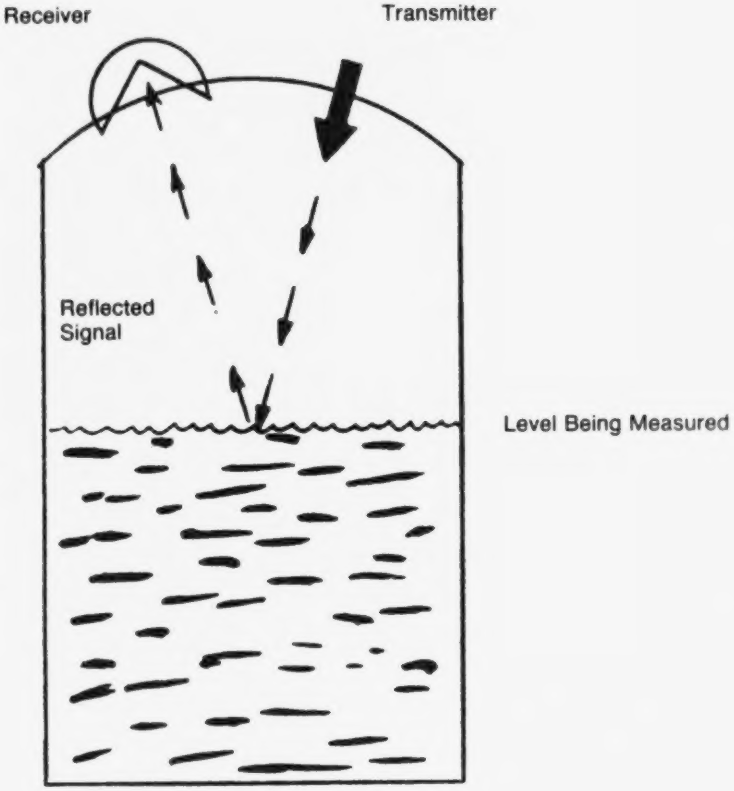
Receiver
Transmitter
Reflected Signal
Level Being Measured

Fig. 4.28 Ultrasonic sound is used to measure liquid levels.

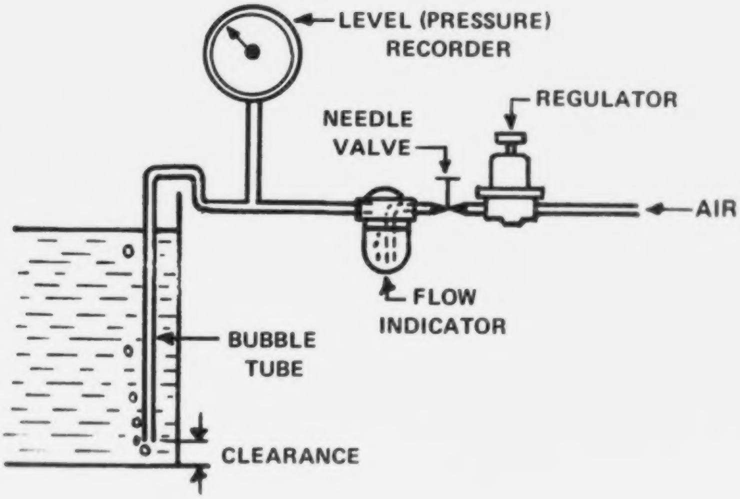
LEVEL (PRESSURE) RECORDER
REGULATOR
NEEDLE VALVE
AIR
FLOW INDICATOR
BUBBLE TUBE
CLEARANCE

Fig. 4.29 A bubbler tube is used to measure liquid level

7. *ANALYTICAL MEASUREMENT*

Most analytical instruments are more fragile, sophisticated, and expensive and also require a greater degree of attention than do most of the routine treatment plant process instruments. These analytical instruments are used mainly in the laboratory. Consequently, their theory of operation is beyond the scope of this section which has been devoted to familiarizing the operator with the basic instruments used in process control.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 227.

4.3A List three different types of temperature-measuring instruments or sensors.

4.3B What are the most common liquids used in manometers to measure pressures?

4.3C Determine the pressure in psi if a manometer reads:

1. 8 inches of water; and
2. 8 inches of mercury.

Assume water has a density of 62.4 lbs per cubic foot and that mercury has a specific gravity of 13.55.

4.4 INDICATORS

We have examined some measuring tools such as rulers which give a direct measurement. Other instruments require a secondary device to make the measurement. For example, a thermocouple needs an electrical meter to indicate and translate voltage (electrical pressure) into temperature readings. The indicators may be as simple as a notch on an oil level dip stick or as complex as a digital readout on a Cathode Ray Tube (CRT) connected to a computer. Indicators also are known as the measuring element and are a part of most instrumentation systems (Fig. 4.30). The indicator may be visual or audio (sound sensed).

Visual indicators usually consist of two major parts, the fixed or moveable scale (unit of measurement) and a movable indicator. In some cases, the fixed scale may be as simple as color coding, such as green for "OK" and red for an unacceptable situation. Most of the indicators in a treatment plant use either a fixed scale and movable indicator (pointer) such as a pressure gage or a movable scale and movable indicator like those used on a circular-flow recording chart.

The scales on an indicator may be straight, curved, or circular in shape. The scale divisions (units of measurement) also may be uniformly divided or unequally divided. For example, a liquid-filled theromometer has equal uniform divisions, but an ohm meter (measure of electrical resistance) has unequally divided scale divisions.

In most cases the units of measurement are direct reading, such as a pressure gage indicating the pressure in psi. However, in some cases it may be necessary to convert the gage reading into some other unit of measurement. An example of this would be a mercury filled U-tube manometer reading 10 inches (24.4 cm) of mercury. We would have to divide the 10 inches of mercury by 2.04 inches of mercury per psi to get a pressure of 4.9 psi.

$$\text{Pressure, psi} = \frac{\text{Height, inches of mercury}}{\text{2.04 inches of mercury/psi}}$$

$$= \frac{\text{10 in. Hg}}{\text{2.04 in. Hg/psi}}$$

$$= \text{4.9 psi}$$

The same type of situation could exist for temperature readings from thermocouples which produce a signal in millivolts which would be converted to degrees by multiplication or division by a conversion factor (K).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 227.

4.4A What is the purpose of transmitting instruments?

4.4B What are the different types of receivers?

4.5 CONTROLLERS

4.50 What are Controllers?

One of the basic objectives of an instrumentation system is the automatic control of measurable process variables (flow, pressure, level, or temperature). Therefore, by the use of primary measurement elements and controllers we automatically measure the process variable, compare it with the desired value (*SET POINT*[2]) and institute some corrective action (change the energy level) if the measured process variable is different from the desired range of values. The process variable also may be simultaneously recorded or monitored as needed.

We will examine some simple process control functions used in treatment plants. Remember that there are many ways to accomplish process control and each system should be tailored to meet the needs of your treatment plant. Usually there are five parts to a control system.

1. *PRIMARY ELEMENT OR SENSOR*

The primary element or sensor is the instrument that measures (senses) a physical condition or variable of interest. A float or a thermocouple would be an example of a primary element. We have just examined many of these types of devices.

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[2] *Set Point. The position at which the control or controller is set. This is the same as the desired value of the process variable.*

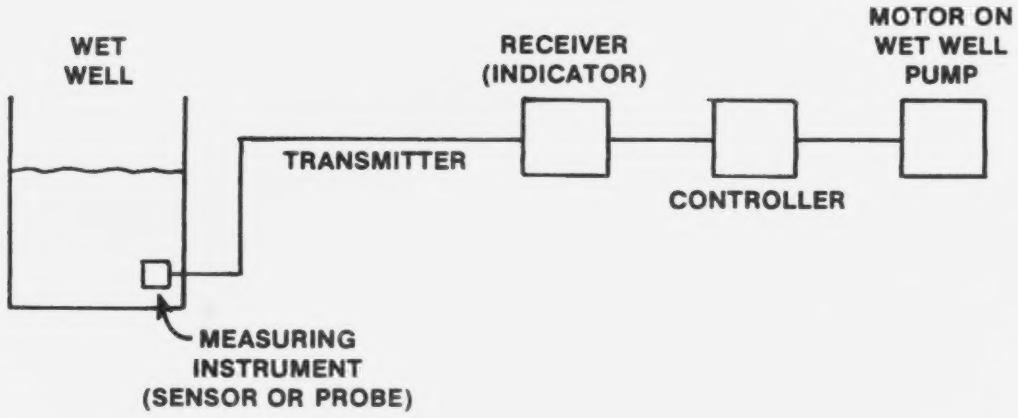
WET WELL
RECEIVER (INDICATOR)
MOTOR ON WET WELL PUMP
TRANSMITTER
CONTROLLER
MEASURING INSTRUMENT (SENSOR OR PROBE)

Fig. 4.30 Instrumentation system.

2. *TRANSMITTER*

A mechanical, hydraulic, pneumatic, or electrical system that transmits a signal from the primary element to the receiving element, and/or control device.

3. *RECEIVING ELEMENT OR RECEIVER*

The receiving element receives the signal or output of the primary element.

The millivolt meter connected to the thermocouple is an example. Another example would be the pressure gage that expresses the level in a diaphragm-box level system.

4. *CONTROLLING ELEMENT OR CONTROLLER*

The controlling element or controller is the device that reacts to the changes in the measured variable. The device may react pneumatically, electrically, mechanically, or hydraulically depending upon the application. An example of this would be an electrical relay connected to the pressure gage from a diaphragm box. Whenever the level reached a previously determined set point, it would cause the pressure gage mechanism to physically move. This movement would trigger a relay to perform some secondary action, such as turning off (switching off) the pump to the tank.

5. *FINAL ELEMENT*

The final element is the device that controls the energy supplied to the process being controlled. The final element could be the pump being turned-off (as in the previous example) or it could be a more sophisticated system where several valve openings would be modulated (changed).

In the previous pressure diaphragm box example, the liquid in the tank is the controlled medium, the controlled variable would be the liquid level in inches or feet (centimeters or meters), and the manipulated variable is the pump being turned on or off. The set point would be a predetermined maximum level the operator selects for the tank. The set point also may be called the control point.

The control system may or may not include facilities to visually or audibly monitor or record the process. Systems which automatically control without indicating the control process are called "blind" systems.

In summary, a control system is a series of devices which measures, compares, controls an energy source, and finally causes some action to be taken automatically to maintain a previously established or desired control variable. The controller may perform this function with or without visual indications or verifications.

4.51 How Do Controllers Work?

The human body is an excellent example of a controller. Let us examine how it works. In the very beginning of this chapter, we used the example of a person opening a door. However, for this example let us have a person desiring warm water for a shower. In this example, the eyes and skin would be the primary sensing elements. The nerves would be the transmitter. The brain would be the receiver and also measuring and controlling elements and the hands would be the final element. When a person first enters a shower, the eyes sense that the shower water is off. The brain measures this message and compares it with the set point of warm water. The brain then activates the hand to turn on both the hot and cold shower faucet handles. If the desired warm water comes out, no other action is initiated since the skin signals (feedback) to the brain that all is "OK." However, if the water is too warm or too cold, the skin signals the brain which again measures the signal from the sensing element (skin) and compares it to the desired set point (warm water) and then signals the right or left hand to adjust either the hot or cold water faucet. This feedback process automatically continues until the desired set point is reached.

Although we have defined what controllers (control elements) are and discussed how a system would operate, we need to better define some of the terminology (name of) and specific control methods.

OPEN AND CLOSED LOOPS

Control systems are divided into two general categories, (1) open loop, and (2) closed loop systems. In an open loop system, there is no information fed back to the controller to change the control function. An example of this would be an automatic lawn sprinkler system operated by a clock-timer. The sprinkler system will operate at the set time every day and for the set watering duration, regardless of whether it is raining or not. In an automatic closed loop system, a moisture sensing device would be added to the sprinkler control system which would tell the controller not to water during a rain or when a moist ground condition exists. In other words, a closed loop system incorporates some sort of feedback mechanism to modify the behavior of the controller.

MANUAL CONTROL

The simplest control system is the manual control system in which the operator senses, measures, and initiates any necessary action. Assuming the operator is alert, it is the most flexible and sophisticated system available since it uses the massive resources and adaptability of the human brain. Our brain probably will never be completely surpassed. However, one of the weaknesses associated with manual control is the lack of consistency or uniformity, since no two people think or act alike, and the human senses are not adequate to monitor all process situations.

ON-OFF CONTROL

The thermostat control for heating is a good example of on-off control. If the set point is set at 68°F (20°C), the controller will turn the heater on at about 67°F (19°C) and shut it off at about 69°F (21°C). Another way to look at it is that the final control element has only two positions (heater on or heater off).

PROPORTIONAL CONTROL

The next more complex level in control systems is the proportional control mode. This system has the capability to give the final control element varying intermediate positions besides on and off. The amount of control exercised is dependent upon how much deviation (difference) exists between the set point and the measured variable (*OFFSET*[3]). An example of this would be three pumps connected to fill a tank. The proportional control system would turn one pump on if the level dropped to ¾ depth; turn two pumps on if that level dropped to ½ depth; and turn on all three pumps if the level dropped to ¼ depth. In other words, the degree of control exercised would be proportional to the need, but the degree of control exercised will not change until the measured variable changes. In this example, three pumps would remain on as long as the level did not exceed ½ depth.

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[3] *Offset (or Droop). The difference between the actual value and the desired value (or set point) characteristic of proportional controllers that do not incorporate reset action.*

PROPORTIONAL CONTROL WITH RESET

Proportional control with reset is a proportional control system with the addition of reset control. Reset control may be thought of as a correction device that cannot function by itself. What reset control does is provide a correction signal to minimize the amount and time the measured variable deviates from the desired set point. As an example, if the control system for a gas water heater had proportional control only, it would regulate the amount of gas sent to the burners based on the amount of water temperature deviation from the set point. However, if we also had proportional control with reset, the reset portion would also fire an additional burner to reduce the amount of time for the measured variable (temperature of water) to reach the set point (water temperature).

PROPORTIONAL CONTROL WITH RESET AND DERIVATIVE

The next more complex control system adds a derivative function to proportional control with reset.

The derivative function controls the rate at which the corrective action takes place based upon the rate at which the measured variable is changing. Therefore, if the control system senses (measures) a slow or small amount of deviation occurring, the proportional control system would most likely handle the situation. However, if a large or rapidly occuring deviation was measured, the derivative control would attempt to increase the action taken by the final element to minimize the amount and time period that the measured variable was under or over the set point.

Let's again use the person desiring warm water for a shower as an example. The measuring elements are the eyes and skin; the measured variables are the water temperature and volume; the control element is the brain, and the final elements are the hands. With on and off control only, the hot and cold water would turn on or off. If we add proportional control, we would turn the faucet on or off proportional to the amount of hot or cold water we desired based on the temperature of the shower water. If we add reset, we would control or turn the hot or cold faucet in anticipation of the water temperature changing due to the *TIME LAG*[4] between the faucet and shower head. Finally, if we add derivative control, we would control the rate at which we turned the faucet handle. That is to say if we were close to the desired water temperature we would turn the faucet handle a small amount very slowly. However, if we were being scalded with very hot water, we would most rapidly turn the hot water off and the cold water on.

RATIO CONTROL

Ratio control is a closed loop system where two or more variables are mixed or metered to a predetermined ratio. An example of ratio control is the blending of two liquids such as adding polymer to wastewater (Fig. 4.31). In this case, the main line flow (wastewater) signal goes to the controller. The controller sends a signal to the secondary flow-control valve (polymer) to control the amount of polymer added. The flow of polymer is also measured and a signal is sent back to the controller to determine if the required amount is being added (closed loop control).

So in summary, we have discussed in simple terms the different classes of controllers and how they are supposed to perform. The actual working components of controllers are complex and sophisticated and some of the features of controllers such as Bandwidth, Reset Rate, and others have been left out for the sake of clarity. In addition, program controllers which control on the basis of time and Cascade controllers which use two controllers for a wider range of controls may also be found in a treatment plant, but have not been included in this discussion in an attempt to keep explanations as simple and straight forward as possible.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 227.

4.5A List the five common parts to a control system.

4.5B What are the common types of control methods?

4.6 RECORDERS

4.60 What are Recorders?

We have discussed "Indicators" (measuring elements) which usually give some visual indication of process status. However, in many cases it is necessary to keep a continuous and permanent record of process variables. To obtain a continuous and permanent record, we normally use some sort of recording device, commonly called a "Recorder".

A recorder is a device that records information onto a sheet of paper that is moving at a specified speed. In this manner, the value of the process variable at any given point in time may be retrieved. Although this information could be taken manually by an operator reading a visual indicator and noting the time, it would be a very burdensome procedure especially if many process variables were to be continuously monitored. Also, in some instances the frequency or location of monitoring required may make it impractical to use operators. Recorders are more practical than having operators take readings every second or take readings in the middle of the night at remote locations where there are no operators.

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[4] *Time Lag. The time required for processes and control systems to respond to a signal or to reach a desired level.*

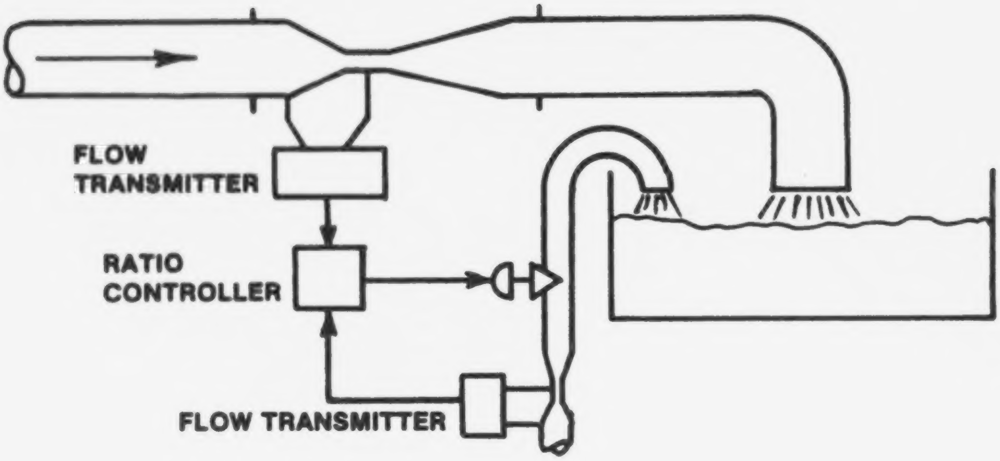

FLOW
TRANSMITTER
RATIO
CONTROLLER
FLOW TRANSMITTER

Fig. 4.31 Ratio control system.

4.61 Types of Recorders

There are two basic types of recorders found in a treatment plant. One type uses a circular chart and the other type uses a long strip of paper (Fig. 4.32). In both cases, the papers have lines indicating the various levels of process variables and time.

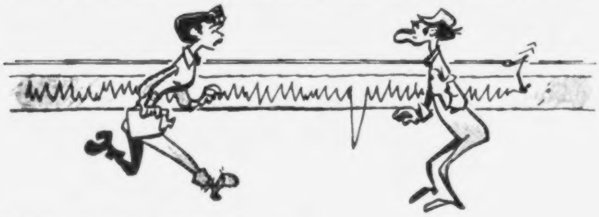
4.610 Circular Chart

In the circular chart, the process variable coordinates are concentric circles radiating outwards and the time frame is shown as arcs crossing the concentric circles. Circular flow charts are sometimes referred to as polar or polar graphic charts.

The chart is mechanically rotated at speeds between 15 minutes and 28 days per revolution, thus covering a wide range of time periods. The size of the chart may vary between 3 and 12 inches (7.5 and 30 cm) in diameter. Circular charts may use up to four recording pens. Each pen records a different variable or measurement.

4.611 Strip Chart

The other commonly used type of recorder is called a "Strip Chart Recorder." Strip charts use a long continuous piece of paper to record data. The chart may move horizontally or vertically with the time frame axis printed horizontally for horizontal recorders and vertically for vertical recorders. The strip may be up to 12 inches (30 cm) in width and available in various lengths. The speed of the strip chart may be moved rapidly for special recordings. The strip may be rolled up or "Z" folded after being marked. Strip charts also have the capability of operating twelve or more marking pens simultaneously.



4.612 Recording Media

Most circular or strip chart recorders use some sort of pen to record the information. Numerous means of inking the pen have been devised to prevent skipping or smearing of ink. In some units ball point, felt tip, electrical stylus, or some other marking device may be used.

4.613 Mechanisms

Recorder mechanisms will vary depending upon what is being recorded. Some circular chart pressure recorders use a modified Bourdon Tube mechanism and a spring-wound clock motor to move the chart. This design does not require any external power source and is suitable for field use. Other recorders require some source of power supply for the chart drive and recording pen mechanisms.

4.7 INTEGRATORS OR TOTALIZERS

Integrators or totalizers are devices that add and/or multiply. They are calculating devices which may operate continuously or intermittently. Some of the devices are mechanically operated and others are electrically powered. They may tally up the amount of digester gas produced or count the number of times a booster pump is switched on. Integrators are sometimes called summators or totalizers. A common example of an integrator would be the odometer on your car's speedometer.

Their basic use in a treatment plant is to sum up the amount of liquid or gaseous flow. This is commonly done by updating a digital counter. The operator usually subtracts the numbers recorded from the previous time period to determine the quantity that was produced or used.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 228.

4.6A What is the purpose of recorders?

4.6B List the two basic types of recorders found in treatment plants?

4.7A What is the basic use of integrators or totalizers in treatment plants?

END OF LESSON 2 OF 4 LESSONS
ON
INSTRUMENTATION

Please answer the discussion and review questions before continuing with Lesson 3.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 4 Lessons)

Chapter 4. INSTRUMENTATION

Please write the answers to these questions in your notebook before continuing with Lesson 3. The problem numbering continues from Lesson 1.

4. How can the depth of water in a wet well be measured or sensed? List as many different types of devices as you can recall.
5. Why are recorders used instead of operators?
6. What is the purpose of a controller or a control system?
7. Why does an operator need to know the rate of inflow to a treatment plant?
8. How does a thermocouple work?
9. Give an example of each of the following types of indicators:
   1. Fixed scale and movable indicator, and
   2. Movable scale and movable indicator.
10. What is the difference between an open and closed loop control system?
11. What is the basic use of an integrator in a treatment plant?

CHAPTER 4. INSTRUMENTATION

(Lesson 3 of 4 Lessons)

4.8 OPERATION

4.80 How Instruments and Controls Affect Plant Operation

So far we have discussed what instruments and controls are supposed to do. Now we will discuss how instruments and controls are used in basic treatment plant operations.

Instrumentation and controls are necessary and often operations are performed automatically because:

1. Time is saved by not having an operator do the job,
2. An operator couldn't do the job.
3. Hiring an operator to do the job would be impractical or too costly,
4. The job can be done better and faster automatically, and
5. An operator would not want to do the job.

The instrumentation and controls in a treatment plant perform a number of small jobs, each simple and repetitious, which would be a nuisance, an annoyance, an inconvenience, a source of errors, or a safety hazard for an operator to perform manually. You must be able to recognize when instruments and controls are not doing their job properly and be able to take command of the situation and do whatever is necessary to make the instrumentation and control systems operate properly. Instruments and controls do not replace operators, but serve as helpers working for the operator.

4.81 Preliminary Treatment

Depending upon the particular design of the treatment plant, the preliminary treatment section could contain instrumentation monitoring and/or controlling the following functions:

1. Influent level (high-low levels),
2. Influent flow (rate),
3. Explosive gas detection (hydrocarbon, LEL),
4. Bar screen operation (On-Off),
5. Grit removal (On-Off),
6. Ventilation system (On-Off),
7. Valves and gates (closed, percent open),
8. Sump pump (On-Off),
9. High water alarm, and
10. pH.

In addition to the above list of instruments and controls, some plants may have influent pump controls, specific ion probes, dissolved solids concentration instruments, or special application instruments or controls such as computers. However, they are beyond the scope of this introductory discussion into the interface of treatment plant operations and instruments and controls. More information may be obtained from the material listed in Section 26.10, "Additional Reading."

1. *INFLUENT LEVEL*

Most treatment plants have some type of level detection system in the influent sewer or channel leading to the bar screens. The level detection system may be a simple high or low water alarm system or the level detection system may actually measure the depth of flow. Operators need to know the depth of flow (or rate of flow) into the plant so that the operator can determine how many bar screens or grit channels to put on-line. Abnormally low flows could indicate an obstruction in the influent sewer line or worse yet, failure in the sewer system. A high water alarm could indicate blockage at the bar screens or perhaps only a partially opened valve or gate hindering the downstream flow. In small plants, an increase in level could mean that some large industrial discharger was on-line and that treatment processes would have to be adjusted accordingly.

High or low water level detection may be done with electrical probes connected to visual or audible annunciators (alarms). The alarm level is usually mechanically adjusted up or down as needed.

The water level detection system may be a bubbler tube system translating air pressure requirements into water level or an ultrasonic proximity device sensing water level by reflected sound waves. A simple stilling well containing a float attached to a cable and indicator also may be used.

2. *INFLUENT FLOW*

One of the most important and necessary pieces of information provided by instruments is the rate of flow and total flow in 24 hours.

The rate of flow (GPM or MGD) determines what and how many units of treatment plant facilities must be on-line at any one time. For example, if each of 3 grit channels is designed to handle 30 MGD (113,550 cu m/day) and the flow rate into the plant is 60 MGD (227,100 cu m/day), two grit channels should be in service. If low flows at night amount to 20 MGD (75,700 cu m/day) only one grit channel should be in service. Finally, if during wet weather the flows reach 80 MGD (302,800 cu m/day), all three grit channels should be on-line.

The daily flow is used to calculate the amount (pounds or kilograms) of suspended solids and organics coming into the plant, and in and out of the various unit processes (assuming additional flow metering is not used). For example, in determining the pounds of suspended solids loading on a plant or treatment process we use the formula:

$$\text{Susp. Solids Loading, lbs/day} = \text{Flow, MGD} \times \text{SS Conc., mg}/L \times 8.34 \text{ lbs/gal}$$

The pounds (kilograms) per day of solids coming into the plant or the pounds (kilograms) per day leaving the plant both require a knowledge of the flow rate:

$$\text{Solids Entering Plant, lbs/day} = \text{Flow, MGD} \times \text{SS In, mg}/L \times 8.34 \text{ lbs/gal}$$

$$\text{Solids, Leaving Plant, lbs/day} = \text{Flow, MGD} \times \text{SS Out, mg}/L \times 8.34 \text{ lbs/gal}$$

The same basic calculation is required to determine the BOD (organic) load and removal efficiencies.

Without accurate flow rate information it would be very difficult, if not impossible, to operate a modern treatment plant efficiently. Accurate flow measurements and records usually are required by regulatory agencies and most plants continuously monitor the flow rate on a circular or strip chart. Therefore, it cannot be stressed too strongly that accurate and reliable flow measurements are necessary in order to properly operate a treatment plant.

3. *EXPLOSIVE GAS DETECTION*

Some of the treatment plants that are subject to receiving wastewater which contains spills of gasoline or other petroleum products have installed an explosive or combustible gas detection instrument. This type of instrument is designed to sense the Lower Explosive Limit (LEL) for hydrocarbons mixed in air.

This type of instrument may be portable or permanently installed. Usually it has some type of sampling pump that passes the air sample across a combustible gas detection cell, which activates an alarm when the LEL is approached. In some permanent installations it may actually shut off electric motors or other ignition sources before the LEL is reached.

The major emphasis given to this type of instrumentation is for safety. This instrument may or may not be useful in detecting hydrocarbon concentrations which affect treatment, but it is unquestionably necessary for safety reasons if the treatment plant is subject to explosive gases or vapors.

4. *BAR SCREEN OPERATION*

Instrumentation or control for a bar screen may consist of a simple in or out of service indicator with manual start and stop switches. This is usually accomplished by connecting a panel light to the bar screen rake or conveyor motor so that the light is on when the motor is running and is off when the motor is off or trips-out on overload. A light indicating availability of power also may be provided. An alarm (usually audible) may be sounded if the bar screen motor trips-out. Another indication of bar screen difficulties would be the rising water level ahead of any plugged bar screen, and subsequently a high water level alarm will sound.

The bar screens are one of the most important pieces of equipment in a treatment plant since all of the plant flow usually must pass through the bar screen. Any plugging or obstruction of the screen usually will result in a lowered water level downstream and an increased water level upstream. If the problem is not immediately resolved, flooding may occur. Although it is possible to bypass the bar screens in many plants, this usually leads to other problems later since rags, trash, and other debris usually caught by the bar screen hang up someplace later in the treatment process.

In most cases the number of bar screens on-line is controlled by the plant influent flow. However, in special cases of heavy rag loads or debris loads, additional bar screens may be put on-line. The bar screenings hopper also may have a level alarm detection device for high levels.

5. *GRIT REMOVAL*

The gravity design grit channels are very simple and reliable in operation. The instruments and controls associated with this system may be an indicator showing whether the grit collection drive system and pumps were on or off. Usually some alarm function also is available for motors tripping out on overload.

The grit hoppers also may contain a grit level detection device or a high grit level alarm. The grit level device usually works on the ultrasonic sound wave principle and is similar to the influent water level sensing instruments. The high level alarms may be electric probes, optical sensors or ultrasonic sound wave instruments.

Usually, aerated grit removal systems would also feature instrumentation to indicate and to control the amount of air being used, and an alarm to indicate high air pressure or loss of air. High air pressure would usually indicate plugging of the grit aerators and loss of air or low pressure would indicate leakage or low water level in the grit tank.

In most plants the number of grit tanks in service is a function of flow and is manually controlled by the operator.

6. *VENTILATION SYSTEM*

Most preliminary treatment ventilation systems consist of single-stage fans or blowers evacuating foul air to the activated sludge process, an odor removal system or direct to the atmosphere. In most cases an indicator light shows which fans are on-off and if power is available to the fans. Alarms indicating motor trip out also may be provided.

A manometer or other low pressure gage also may be used to show the air pressure in the air duct. This is one means of determining whether the proper amount of foul air is actually being removed. As an example, the fan motor may be running but failure of the vee belts to the fan would result in no air transport.

The ventilation system must be kept operating both for the operator's safety and for minimizing the accumulation of concentrations of moist or otherwise corrosive and toxic gases.

7. *VALVES AND GATES*

Motor-operated gates and valves are usually monitored to indicate whether they are opened, closed, or percent open and if power (air or electrical) is available to the motor operator. The valves and gates also may be remotely opened or closed in many cases, as well as being controlled locally.

Gates and valves control the flow of wastewater in a treatment plant and their proper operation is absolutely essential to efficient treatment plant operations. Motor-controlled gates may be used ahead of bar screens and grit tanks. They also usually feature limit switches that cut the power off to the motor operators when a gate reaches the top or bottom of its travel. Without this provision, the gates or valves are likely to jam themselves open or closed or, worse yet, some structural failure of the system could result. Large butterfly valves can be modulated (partially opened or closed) to keep a constant flow rate to one battery (portion of a treatment process such as one clarifier) of the plant and the remaining flow would be diverted to another battery.

8. *SUMP PUMP*

Usually a sump pump has indicators showing power availability and whether it is on or off. However, in some cases a level sensing and control system will turn on a second set of pumps if the flow is greater than that which can be handled by one pump.

A common system could incorporate the use of a float connected to a switch. When water enters the sump, it raises the float which trips a switch starting the sump pump motor. After the pump dewaters the sump, the float drops tripping the switch and turning the pump off.

9. *HIGH WATER ALARM*

In basements or pipe galleries, high water alarm probes are usually installed to alarm any possible flooding conditions that may occur. The devices are usually electrical probes that short out when touched by water and ring an audible alarm.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 228.

4.8A List as many functions in the preliminary treatment section as you can recall that could contain instrumentation.

4.8B Why does an operator need to know the influent level to a plant?

4.8C How can gasoline or other petroleum products be detected in a wet well?

4.8D Why should wet well ventilation systems be kept operating continuously?

4.82 Primary Treatment

Primary treatment usually consists of gravity sedimentation tanks with facilities (flights) to scrape the settled organic solids into a sludge hopper or sump; facilities to move floatable materials into grease or scum troughs or boxes; and weirs to control the flow of the clarified effluent.

Usually an operator would be concerned with the following instrumented activities in primary treatment:

1. Collector drive motor, ON-OFF — Power Available,
2. Flights, running — stopped,
3. Grease skimmers, ON-OFF — Power Available,
4. Primary sludge blanket depth, feet or inches (meters or centimeters),
5. Primary sludge pumps, ON-OFF — Power Available,
6. Primary sludge draw-off valve, OPEN-CLOSED — % Open,
7. Primary sludge flow (gpm or *L*/sec),
8. High water alarm, Audible — Visible, and
9. Water level control valve, Closed — % Open.

Some treatment plants may have additional facilities which are instrumented, such as primary influent or effluent channel aeration, secondary treatment flow diversion or control systems, temperature probes, and others depending upon the specific situation.

1. *COLLECTOR DRIVE MOTOR*

Depending upon the location of the power control panel and the operations control room, the drive motors usually have colored lights indicating that power is available, and whether the motor is "ON" or "OFF". The motors usually have "local" (on-site) on and off switches, circuit breaker switches at the electrical power panel, and in addition may have control switches in the central control room.

2. *FLIGHTS*

A flight movement-detection system is used to ensure that sludge is being continuously moved. In some instances the collector chain may fail and scraping of the primary (raw) sludge to the discharge point would cease even though the collector drive motor would still be operating.

Unless flight movement failure is promptly detected and the primary tank is taken out of service, dewatered and washed down, serious odor problems could result as well as transfer of septic wastes to the secondary treatment system, which would negatively affect the process. The actual flight movement detection system may be as simple as a pivoted stick which moves everytime a flight strikes it. A more sophisticated flight detection system uses a proximity device which sends out an ultrasonic signal which is reflected everytime the flight passes by. An alarm signal would be generated if a signal is not reflected back after a specified time delay.

3. *GREASE SKIMMERS*

Grease skimmers are usually rotating blades driven by an electric motor. Their function is to scrape and push floatables (grease-oils) into a trough for transport to further treatment. In most cases the grease skimming operation is relatively simple and reliable. Complexity of the skimming operation depends on the amount of floatables being removed in the primary tank. The skimmers may be operated continuously or only once a shift depending upon the load of scum and floatables.

The controls for the grease skimmer drive motors are similar to those used for flight collector drive motors. There are usually colored indicator lights showing power available and whether the units are on or off. The drives may be turned on and off locally, or remotely in the central control room. In some installations, a timer may be incorporated into the skimmer drive control to regulate the amount of time the skimmers operate each period.

4. *PRIMARY SLUDGE BLANKET DEPTH*

One of the important measurements in the operation of primary sedimentation tanks is the primary sludge blanket level. Unless the proper level is maintained by controlling the removal of sludge from the tanks, two situations could occur. One problem develops when high blankets and poor suspended solids and BOD removal efficiencies occur in the primary tanks. The other is the removal of dilute sludge or, in the worst case, primary wastewater instead of sludge from the sludge hopper.

Sludge blanket depths may be manually measured by using a hose and an aspirator. This is done by lowering the hose into the tank until sludge comes out of the aspirator and then measuring the length of hose used.

Another method of measuring blanket depths uses two ultrasonic transmitters and receivers (probes), one for low level and one for high level. The height of the low and high level probes are mechanically set at the desired minimum and maximum blanket levels. Whenever the sludge blanket level drops below the desired minimum, a signal is generated which may turn on an indicator light, alarm or turn off the sludge pump. Conversely, when the sludge blanket level exceeds the maximum desired level, another indicator light or alarm may come on or the sludge pump may be turned on depending upon the specific design.

The probes operate on the principle that the denser sludge mixture attenuates (decreases) the signal level between the ultrasonic transmitter and receiver more than that which would occur due to wastewater alone. The changes in signal level correspond to the sludge blanket density. Under these circumstances, the lower probe should always indicate an attenuated (decreased or diminished) signal and the upper probe should indicate an unattenuated (undiminished) signal.

5. *PRIMARY SLUDGE PUMPS*

One of the most important and critical operations in the primary treatment system is the proper operation of the primary sludge pumps. Under-pumping can result in high sludge blankets and poor removal efficiencies in the primary tanks. When this happens the suspended solids and BOD capture efficiencies could be adversely affected. Under the worst circumstances, when a pump does not work, a situation similar to that of inoperative flights caused by a broken collector chain would result. These circumstances could produce odors and septic wastes.

Over-pumping, on the other hand, can send very dilute primary sludge to the anaerobic digesters and cause problems in digester operation by reducing the hydraulic detention time and temperature and also by wasting energy by unnecessary pumping.

Again the basic controls for the pump motors would consist of colored lights to indicate power availability, and whether the motor was on or off. The control switches are usually located next to the pumps and also may be duplicated in the central control room.

The amount of pumping can be regulated by manually turning the pumps on and off, by using a timer control to turn the pumps on and off for a given number of minutes each hour in sequence or by using a signal from a sludge density meter control to turn the pumps off after the pumps have been turned on manually or by timer sequence.

6. *PRIMARY SLUDGE DRAW-OFF VALVES*

In some treatment plants, primary sludge is removed from the tanks by a *HYDROSTATIC SYSTEM*[5] (gravity) instead of using pumps. In these installations the controls usually operate a motorized valve. Indicator lights usually show whether a valve is open or closed. In addition, there may be an indicator (meter) located in the control showing what percent the valve is open with a switch to power the valve open or closed. A mechanical indicator is usually attached to the valve itself to indicate the valve position.

A timer system also may be incorporated to open each valve a predetermined amount for a set number of minutes each hour.

A sludge density meter also may be used to control the closing of each draw-off valve. In this case when the primary sludge density drops below a pre-set limit, for example four percent, a signal is generated closing that particular valve and opening the valve in the next tank. This process is continuously repeated.

7. *PRIMARY SLUDGE FLOW AND PRESSURE*

Most treatment plants carefully meter the amount of primary sludge that is withdrawn and sent to the anaerobic digestion system. The amount of flow per day is used to compute the volatile solids quantity and distribution to the digesters. Improper metering could result in shock overloads to the digester which could upset the process. The percent solids of the primary sludge and its volatile solids content are usually analyzed in the laboratory. However, a sludge density meter may be used to determine the percent solids concentration and a historically valid number for the percent volatile solids may be used in the calculations:

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[5] *Hydrostatic System. In a hydrostatic sludge removal system, the surface of the water in the clarifier is higher than the surface of the water in the sludge well or hopper. This difference in pressure head forces sludge from the bottom of the clarifier to flow through pipes to the sludge well or hopper.*

$$\text{Digester Loading, lbs VS/day} = \text{Prim Sl, }\frac{\text{gal}}{\text{day}} \times \frac{8.34\text{ lbs}}{\text{gal}} \times \frac{\text{Tot Sol, \%}}{100\%} \times \frac{\text{Vol Sol, \%}}{100\%}$$

or

$$\text{Digester Loading, kg VS/day} = \text{Prim Sl, }\frac{\text{liters}}{\text{day}} \times \frac{1\text{ kg}}{1\ L} \times \frac{\text{Tot Sol, \%}}{100\%} \times \frac{\text{Vol Sol, \%}}{100\%}$$

The primary sludge flow is usually metered by a Venturi meter, or a magnetic flow meter, although other closed-conduit metering devices may be used. The signal from the flowmeter is usually transmitted to a read out device (meter) and flow recorder (circular or strip chart). An integrator is usually included to determine the total sludge flow per day. The flow readings may be indicated locally or in the central control room.

Besides knowing the flow rate and total flow, the operator also is interested in the primary sludge line pressure. Higher than normal pressure readings usually indicate a possible obstruction in the line or that the line is due for routine cleaning. In most cases, a pressure gage is mounted directly on the line; however, a pressure transducer may be used to transmit a signal to a remote indicator in the central control room.

8. *HIGH WATER ALARM*

A high water alarm system is usually incorporated into the primary treatment system to indicate potential or possible flooding. The alarm systems are usually identical throughout the plant and they are discussed in the preliminary treatment section.

9. *WATER LEVEL CONTROL VALVE*

Modulating (regulating or adjusting) butterfly valves are used in some plants to control the flow into each primary tank in an attempt to equalize the flow and water level in each tank. This will promote the most efficient use of the tanks in service. When some tanks get more flow, their suspended solids and BOD capture efficiencies usually drop and cause an overall decrease in treatment efficiency.

The actual operation of a level control system usually incorporates some type of level detection device (probes or proximity device) which transmits a signal to a motorized valve. The water level signal and percent opening of the valve are calibrated together to obtain the desired water level in each tank. If the water level is dropping, the valve would open more and if the water level is rising, the valve would close. The percent open of each valve is usually read at the motorized valve operator and in most cases should change with the change in flow.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 228.

4.8E List the instrumented activities that could concern an operator in primary treatment.

4.8F How can movement of flights be detected?

4.8G How can sludge pumps be controlled or regulated?

4.8H Why are butterfly valves used in some plants to control the flow to each primary tank?

END OF LESSON 3 OF 4 LESSONS
ON
INSTRUMENTATION

Please answer the discussion and review questions before continuing with Lesson 4.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 4 Lessons)

Chapter 4. INSTRUMENTATION

Please write the answers to these questions in your notebook before continuing with Lesson 4. The problem numbering continues from Lesson 2.

12. Why are operations performed automatically by instrumentation and controls?
13. Why are accurate flow measurements and records important?
14. How would you determine if a wet well ventilation system was working?
15. What problems can develop if an improper sludge blanket depth is maintained in a primary clarifier?

CHAPTER 4. INSTRUMENTATION

(Lesson 4 of 4 Lessons)

4.83 Activated Sludge Process

After primary treatment, wastewater can be further purified by secondary treatment. One of the common forms of biological secondary treatment is the activated sludge process. In this process, dissolved and colloidal organic wastes not removed by primary treatment are broken down and stabilized by bacteria in the presence of air.

In the activated sludge process, primary effluent is gently mixed into a biological culture (mixed liquor suspended solids or MLSS) by air diffusion in the aeration tank. After a period of time, the mixture (MLSS) is sent to the secondary clarifiers where the biological floc settles out. Part of the settled biological floc (return activated sludge or RAS) is returned to the aeration tank and the excess biological floc (waste activated sludge or WAS) is sent to the head of the primary sedimentation tanks or to some other alternative sludge treatment process. In order for the process to function properly and efficiently, the operator must carefully control (balance) the amounts of organic waste, biological floc, and air in the aeration tanks. Since the operator usually has little or no control over the amount of organic waste coming into the aeration tank, the operator can only control (balance) the amount of biological mass (MLSS) and air used.

Usually, an operator would be concerned with the following instrumented activities in the aeration part of the process:

1. Primary effluent flow (MGD or cu m/day);
2. Aeration air rate (cfm or cu m/sec);
3. Aeration air pressure (psi or kg/sq cm);
4. Air compressor — ON-OFF, Power Available, Temperature (°F or °C) of Air and Oil, Speed (rpm), % Vane Opening, Oil Level, Oil Pressure and Blower Vibration;
5. Mixed liquor suspended solids (mg/*L*);
6. Dissolved oxygen concentration in the mixed liquor suspended solids (MLSS) (mg/*L*); and
7. Final sedimentation tanks (Influent Flow, Return Activated Sludge Flow (RAS), and Waste Activated Sludge Flow (WAS).

Other laboratory information is also necessary to operate the activated sludge process, for example, BOD and COD, suspended solids, percent volatile solids, sludge settleability, and sludge volume index (SVI).

1. *PRIMARY EFFLUENT FLOW*

   In many cases the primary effluent inflow is the same as the plant flow, except in cases where only part of the flow receives secondary treatment, where there are process recycle flows, or there are sidestreams such as cooling water flows. Flow rate and 24-hour total flow are usually measured in terms of million gallons per day (cu m/day). Accurate flow measurements and laboratory data are necessary to determine the organic loading in the aeration system and for information such as the air rate per gallon (cu m) of wastewater treated.

   Flow rates are usually recorded on a circular or strip chart and the total flow is obtained from an integrator or totalizer. The flow sensing, indicating and recording devices have been previously discussed as part of preliminary treatment instrumentation.

2. *AERATION AIR RATE*

   The aeration air flow rate is usually measured in terms of cubic feet per minute (cfm) or cubic meters per second (cu m/sec). The air flow rate may be measured at each air compressor or be read as a total from the main air header, usually by a differential pressure metering device such as an orifice plate.

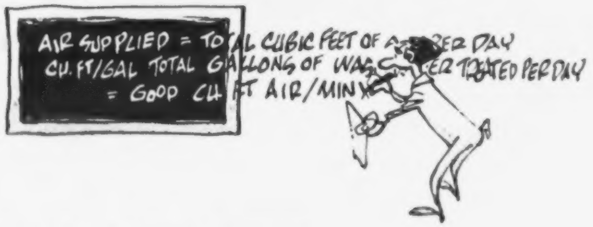
Accurate air flow measurements are very important because oxygen (air) is one of the basic components in the activated sludge process. Insufficient or under-aeration process air will usually result in under-treatment and poor effluent quality; while excess or over-aeration will waste energy and unnecessarily stress and wear the air compression system.

In most conventional activated sludge treatment plants, air is supplied at the rate of 1 to 2 cubic feet of air per gallon (0.13 to 0.26 cu m of air per cu m) of wastewater being treated. For example, in a 5 MGD plant the air rate may be 6,000 cfm (2.8 cu m/sec). To determine the air rate per gallon of wastewater treated, perform the following calculation:

$$\begin{aligned}\text{Air Supplied, cu ft/gal} &= \frac{\text{Total Cubic Feet of Air per Day}}{\text{Total Gallons of Wastewater Treated per Day}}\\ &= \frac{6000 \text{ cu ft air/min} \times 1440 \text{ min/day}}{5{,}000{,}000 \text{ gallons wastewater/day}}\\ &= 1.728 \text{ cu ft air/gallon treated}\end{aligned}$$

or

$$\begin{aligned}\text{Air Supplied, } \frac{\text{cu m air}}{\text{cu m water}} &= \frac{\text{Total Cubic Meters of Air per Day}}{\text{Total Cubic Meters of Wastewater Treated per Day}}\\ &= \frac{2.8 \text{ cu m/sec} \times 60 \text{ sec/min} \times 1440 \text{ min/day}}{19{,}000 \text{ cu m/day}}\\ &= 12.7 \text{ cu m air/cu m water}\end{aligned}$$


AIR SUPPLIED = TOTAL CUBIC FEET OF A PER DAY
CU.FT/GAL TOTAL GALLONS OF WAS ER TREATED PER DAY
= GOOD CU FT AIR/MIN

3. *AERATION AIR PRESSURE*

Besides the air flow rate, another important measurement is air pressure. Abnormally high or low air pressures usually indicate clogged air diffusion devices or air leaks.

Pressure gages are usually placed at the air compressors and also downstream at main aeration lines. A difference in pressure between the two points would indicate head losses (pressure losses) due to partially closed valves or other restrictions, such as before and after air filters.

Most aeration systems operate at about 7 psig (0.5 kg/sq cm) to overcome the static head on submerged diffusers. Bourdon tube pressure gages are commonly used to measure pressure directly. The read-out of pressure is usually transmitted and also displayed in the control room by use of pressure transducers. Unlike air flow, air pressure is usually fairly constant and usually is not automatically recorded.

4. *AIR COMPRESSOR: ON-OFF, POWER AVAILABLE, TEMPERATURE (AIR AND COMPRESSOR OIL), SPEED, % VANE OPEN, VIBRATION, RUNNING HOURS, OIL LEVEL, AND OIL PRESSURE*

Besides the air flow, pressure and temperature, it is necessary to know other facts about the air generation system.

In multi-air compressor systems, a read-out (from either TV screen (CRT) or computer print-out) is provided to show what compressors are operating and if power is available (for electricity driven compressors) or the status of other fuel supply systems (for example, how much diesel fuel is in the storage tanks). Available fuel volumes may be measured by a float or other sensing devices which will indicate the amount of fuel remaining. Also, air compressor failure or power failure alarms are usually incorporated into the system. As discussed previously for electrically operated equipment, the ON-OFF indicator lights are wired into the power supply. Liquid fuel volume indicators usually have float or similar types of level indicators that are calibrated to read in terms of gallons (cubic meters) or fractions of tank capacity.

Another important measurement in air compression operation is the temperature of both air and lubrication oil. Excessive compressed air temperatures may indicate an open bypass valve or other possible mechanical malfunctions. Excessive lubrication oil temperatures may indicate motor overload, low oil levels or inoperative oil coolers. High oil temperatures usually trigger alarm circuits and also may automatically shut the compressor off in some installations.

Ambient (surrounding or room level) air and compressed air temperatures may be measured directly by the use of bimetallic thermometers or capillary bulb thermometers in the air stream. However, remote reading thermometers will commonly use some sort of a thermocouple for gas or oil temperature sensing.

Compressor speed in terms of RPM is used by the operator to determine if the proper amount of air flow and pressure is resulting from a given RPM for engine-driven compressors. Most air compressors operate efficiently within given RPM ranges; however, low ranges are very inefficient while high speeds may damage the equipment or cause the motor to overheat.

The RPM is usually measured by a mechanical drive tachometer, electrical generator tachometer, electrical impulse tachometer, or photo electric tachometer. All except the mechanical drive tachometer allows for remote signal transmission and read-out of RPM.

Constant RPM electrically driven air compressors modulate the inlet air vanes to control air discharge output. This information is usually read as percent opening of the inlet vanes.

Some compressors, usually electrically driven, are equipped with vibration sensing devices. These devices are designed to sense displacement, velocity, or acceleration. They are basically a safety device to shut down the compressor and initiate an alarm if the compressor or motor starts to vibrate excessively due to any unbalanced forces or loose floor connections.

Both internal combustion and electrically driven air compressors usually have some sort of Hour-Meter to determine how many hours each unit has operated since the last repair or overhaul. To equalize wear, compressors are usually rotated after so many hours of operation. Also the Hour-Meter can be used to schedule preventive maintenance functions such as oil changes.

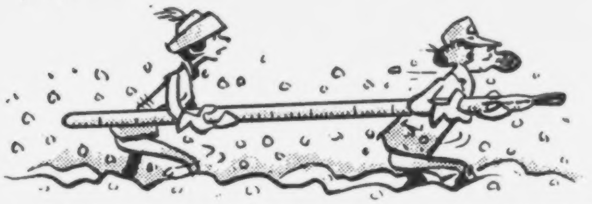
Most Hour-Meters are a form of electric clock that registers the number of hours on a totalizer. The hours of running time may be indicated at the compressor control panel and/or remotely indicated in a central control room.

Electrically driven compressors also usually have an ammeter read-out for indicating power consumption. The ammeter also may be set to signal an alarm and/or shut off the compressor when it is overloaded.

Another important measurement is that of oil level. The measurement may be manually performed by a dip stick, read from a sight glass, or by use of other level sensing devices (electronic or ultrasonic systems) which may initiate alarms if the oil level is too high or too low.

5. *TEMPERATURE OF MIXED LIQUOR SUSPENDED SOLIDS (MLSS)*

Temperature changes greatly influence all biological processes. You must carefully monitor the temperature of the mixed liquor in the activated sludge process. The biological metabolism rate (activity) increases with temperature increases and decreases with decreasing temperature. Consequently, more biological mass is required during cooler temperatures to obtain the same degree of treatment. Therefore, you must increase the MLSS concentration during the cooler months and decrease it during the warmer months in accordance with the particular conditions at the plant.



The temperature readings may be taken and recorded manually or they may be continously monitored and recorded on a chart. The temperature may be sensed by any of the previously described temperature sensing devices.

6. *DISSOLVED OXYGEN CONCENTRATION*

In some activated sludge plants, dissolved oxygen (DO) meters are provided to monitor the level of dissolved oxygen in the aeration mixed liquor suspended solids.

The oxygen level in mg/*L* is monitored to ensure that adequate oxygen (air) is being provided in the aeration tanks. A dissolved oxygen level of 1 to 4 mg/*L* is usually maintained in the aerators, depending upon the particular requirements of the given activated sludge process.

The oxygen level is measured by a probe and meter. The probe may be portable or permanently installed in the aerator. Single or multi-probes may be installed in one or more aerators. At the present state of development, most DO meters are basically lab instruments and should be treated with care. The probes require frequent cleaning and the meters should be calibrated routinely to ensure their accuracy.

In some plants the output from the DO meters controls the aeration blowers (compressors) thereby theoretically optimizing the air flow rate to the biological culture in the aeration tanks. Remote oxygen level read-outs are usually indicated and recorded along with the corresponding air rates.

7. The instrumentation and control of the final secondary sedimentation tanks are very similar to the primary sedimentation tanks. For all practical purposes, the following operations are identical:

   a. Collector drive motor,
   b. Sludge blanket depth,
   c. Sludge pumps,
   d. Sludge draw-off valves, and
   e. High water alarm.

The operation of the sludge pumps for return activated sludge (RAS) and metering may vary slightly from primary sludge pumping and metering since usually only part of the flow (25 percent up to 100 percent) is returned to the aeration tank; the remaining waste activated sludge (WAS) is usually routed back to the head of the primary tanks or to some other sludge handling process.

Consequently, the total RAS flow and WAS flow may be metered or the RAS flow to the aeration tanks and the WAS flow may be monitored. In either case, it is important to have accurate measurements of RAS and WAS flows to calculate the return rate, and the Mean Cell Residence Time (MCRT).

A turbidimeter is used in some plants to monitor the effluent quality from the secondary sedimentation tanks. In on-line turbidimeters, a pump directs a small stream of final effluent across a light beam. The scattering or attenuation of the light beam due to particles in the effluent is measured and indicated in turbidity units. The turbidity may be continuously monitored or measured from grab samples analyzed in the lab. The process used is commonly dictated by the legal monitoring requirements specified in the NPDES permit for the plant.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 228.

4.8I How is air flow measured?

4.8J Where are air pressure gages usually placed in the aeration system of the activated sludge process?

4.8K How are oil levels in air compressors measured?

4.84 Anaerobic Sludge Digestion

The settled organic solids from the primary sedimentation tanks and the waste activated sludge from secondary treatment require further processing. One common method of processing and treating the sludge is "anaerobic sludge digestion." Under ideal environmental conditions, anaerobic bacteria stabilize and convert most of the organic matter into methane gas, carbon dioxide gas and water. In this airless process, you must carefully control the amount and rate of sludge feeding to the digester, the operating temperature of the digester, and the rate of change of temperature. Excessive organic loadings or temperature changes adversely affect the anaerobic bacteria and can cause an upset of the biological treatment process.

The following activities are usually instrumented or controlled:

1. Raw sludge feed controller,
2. Digester tank level and alarms,
3. Digester sludge flow,
4. Digester gas flow,
5. Digester gas pressure,
6. Digester sludge temperature,
7. Digester heating system (steam, hot water),
8. Digester transfer and recirculation pumps,
9. Digester gas quality,
10. Combustible gas alarm, and
11. Digester gas mixing compressor.

1. *RAW SLUDGE FEED CONTROL*

Feeding the digester(s) with primary sludge may be a relatively simple operation in small primary treatment plants with only one or two digesters. In these situations the primary sludge is intermittently fed to the digester whenever the sludge pumps are activated. The sludge solids and volatile solids concentrations are analyzed in the laboratory. The flow may be metered or estimated from the pump curves and time of pump operation. Loadings are calculated on the basis of solids concentrations and flows. In all systems the pumping is either controlled by the sludge blanket depth or sludge concentration.

However, in larger plants with many primary tanks and digesters, more sophisticated controls are necessary since large volumes of primary sludge must be continuously distributed to many digesters. In addition, not all digesters are loaded at the same rate since individual digesters may have varying operating capacities. For example, a modern, clean, heated, and gas-mixed digester may be loaded between 0.1 and 0.2 pounds of volatile solids per day per cubic foot (1 and 2 kg VS/day/cu m) of digester capacity. Uncleaned, unmixed digesters may be able to handle only 0.05 lbs VS/day/cu ft (0.5 kg VS/day/cu m). Consequently, a well operating and closely controlled primary sludge feed system is essential.

As an example, a primary sludge feed system would pump all of the primary sludge to one battery (row) of digesters for a set period of time or for a set volume such as so many gallons (cubic meters). In either case, the calculations would be based on the pounds (kilograms) of volatile solids pumped during that time period to that battery. Next, each digester in that battery would be fed the desired amount of sludge (pounds or kilograms of volatile solids) controlled by the amount of time a valve to that digester was open, the percentage opening of the valve, or the gallons (cubic meters or liters) of sludge metered into that particular digester. The gallons (cubic meters or liters) of sludge metered in the last case may be monitored by a flow meter or by the change in digester tank level. Therefore, in its most basic form, much of the control is done manually by the operator. In the most automated form, the control is performed by *SOFTWARE PROGRAMMING*[6] from a computer. In most cases, each battery of digesters is loaded in sequence or by level priority continually around the clock.

Ideally, the control system would permit continuous loading of all digesters in proportion to the pounds of volatile solids being sent to the digestion system. Such a system would proportion a part of the total primary sludge flow to each digester by having a flow meter and automatic control valve at each digester. In addition, the digested sludge flow withdrawal rate would also be automatically controlled to maintain a set or desired level in the digester. In order to obtain this level of control, a process control computer would be necessary and discussion of such a system is beyond the scope of this chapter.

2. *DIGESTER TANK LEVEL AND ALARMS*

Almost all digester tanks have some means of determining their liquid level. Some of the older digesters use simple overflow pipes. An example is the opening of an overflow pipe at the desired digester level and pumping primary sludge into the digester until digested sludge overflows from the pipe. Other systems use a variable-level swing overflow pipe in which the discharge level of the pipe is raised or lowered to the desired level and primary sludge coming into the digester automatically displaces or forces digested sludge out of the overflow.

These examples obviously require the operator to be at the digester to determine or change the level. Other level control systems may use a pressure transducer calibrated to translate liquid hydrostatic pressure into feet (meters) of sludge in the digester. The tank level may be indicated and recorded in the control room from where it would also be possible to raise or lower the level by operating powered remote control valves.

In addition to digester tank levels, most systems use some type of high or low level alarm. The alarms may be triggered by any of the previously discussed level sensing instruments or software sensing devices which detect when levels are too low or too high. A low level alarm could indicate that a digested sludge valve was accidently left open, a possible control system malfunction, or a possible leak or break somewhere in the system. A high level alarm could indicate plugging of the overflow, a control system malfunction, or an inoperative digested sludge withdrawal system.

3. *DIGESTED SLUDGE FLOW*

The digested sludge is not metered in some plants because the operators assume that digested sludge flow equals the primary sludge flow. For small plants with one or two digesters, this assumption is probably acceptable. However, in large plants with large capacities it is important to know the digested sludge flow pattern. This permits monitoring of the rate and frequency of withdrawal and provides a verification of the primary sludge flow. Flows may be monitored from each tank, battery of digesters, or total digested flow.

Venturi meters or magnetic flow meters are commonly used to measure the digested sludge flows. Flow data are usually recorded, especially in situations where the digested sludge receives additional treatment, such as dewatering or chemical conditioning. The flow rate and total flow are usually recorded at the control room.

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[6] *Software Programs. Computer programs designed and written to monitor and control wastewater treatment processes or other processes.*

4. *DIGESTER GAS FLOW*

Gas production from each digester is monitored daily. This information is used to analyze the volume of gas production per pound (gram or kilogram) of volatile solids added and destroyed. Gas production is also a strong indicator of digester performance with low gas production usually indicating some type of problem.

Since digester gas pressure is relatively low, about 8 to 12 inches (20 to 30 cm) of water, metering systems with very low head losses must be used. Also, the meters must operate over a fairly wide range of gas flows. Positive displacement meters and turbine meters are commonly used to measure gas flows. The total gas production may be manually determined from daily mechanical integrator readings of the gas production rate, or it can be automatically monitored continuously and recorded in the control room.

5. *DIGESTER GAS PRESSURE*

Digester gas pressure must be monitored to ensure that the safety valves are operating properly (fixed cover digesters). Although the gas pressure is relatively low, usually 8 to 12 inches (20 to 30 cm) of water, higher pressures may seriously over pressure the digesters and a low pressure may indicate gas leakage from the system.

The gas pressures in many digesters are monitored by the use of water-filled manometers. Since the gas pressure is relatively constant, it is usually not automatically monitored and recorded, but visually checked by an operator during every shift.

6. *DIGESTER SLUDGE TEMPERATURE*

One of the most important operating controls is digester temperature. To achieve efficient digestion, the temperature should be maintained near 95°F or 35°C (mesophilic operations). Therefore, nearly every digester has some type of built-in temperature sensing device. Thermocouples are commonly used with remote readings in the control room. Temperatures are usually continuously recorded on a circular chart. Manual temperature readings may be made by placing a thermometer in sludge running into the sample sink.

7. *DIGESTER HEATING SYSTEM*

Assuming that the digesters are heated either by direct steam injection, steam eductors, or by steam-heated exchangers, some means of indicating the rate of steam flow and the total pounds of steam used per day is necessary. Usually, steam pressure is also monitored. Steam to each digester is usually controlled by remotely controlled steam valves. The percent opening and length of time each valve is opened is determined by the temperature in the digester. A fully automated digester heating system would use a process controller to sense the difference between the existing digester temperature and the set point temperature and route steam (heat) according to the needs of each digester. This process controller would also control the steam production of the steam boiler to match the digester heating needs.

8. *DIGESTER TRANSFER AND RECIRCULATION PUMPS*

Transfer and recirculation pumps are an important part of anaerobic sludge digestion operation. The pumps are used to mix the digester contents, transfer sludge between digesters, pump out digested sludge and pump supernatant out of digesters. Several pumps are usually interconnected to maximize flexibility of operations.

The instrumentation and control of the transfer or recirculation pumps are very similar to primary sludge and return activated sludge pumping operations.

9. *DIGESTER GAS QUALITY*

In some plants, automatic means of analyzing digester gas quality is provided. Either the carbon dioxide (CO_2) or methane (CH_4) gas content is analyzed and the read-out is usually given in percent carbon dioxide or methane.

The percent of carbon dioxide or methane in digester gas is usually a good indicator of the status of the biological process. Digestion gas usually contains 60 to 70 percent methane and the remainder is considered to be carbon dioxide gas. Upset digesters tend to have a much lower percentage of methane gas and a higher percentage of carbon dioxide gas, for example, 40 to 50 percent CH_4 and 50 to 60 percent CO_2.

The digester gas quality can be measured at the digester itself or a small side stream of digester gas may be pumped to the analyzer from the digester or the main gas line. In most cases, digester gas tends to be saturated with moisture and some type of moisture trap or drier is necessary to protect the analyzer. Also, some digester gases tend to have significant amounts of corrosive hydrogen sulfide (H_2S) gas and a means of absorbing the H_2S also may be necessary.

A gas chromatograph may be used to perform the gas analysis. Instruments like the gas chromatograph and spectrophotometers are basically laboratory instruments and require significant skill and knowledge to operate and maintain them.

10. *COMBUSTIBLE GAS ALARM*

In plants where there are tunnels or other confined spaces, a combustible gas alarm may be provided. This instrument is essentially identical to the explosive gas detection instrument described in the preliminary treatment section. This device is calibrated to activate an alarm at a set Lower Explosive Limit (LEL). If the tunnels or other spaces being monitored do not have a good ventilation pattern in which to place the detector, a sample pump may be built in to pass air over or through the detection device. The purpose of the instrument is to detect any explosive gas leaks or to detect the generation of explosive gases in confined spaces for the safety of the plant and operators.

11. *DIGESTER GAS MIXING COMPRESSOR*

In most modern treatment plants, some form of digester gas mixing is usually provided. Gas mixing is one of the more popular means of mixing the digester. Digester gas compression is similar to aeration air compression with the following differences: (1) the volume is much less, (2) the pressure is usually higher, (3) digester gas tends to be saturated with moisture and contain particulate impurities, and (4) for higher pressure, reciprocating compressors may be used instead of centrifugal or rotary vane types.

As a rule, the gas mixing volume and pressure remain constant and consequently the load on the compressor and its driver also remain constant. Depending upon the design, individual compressors may be provided for each digester, or several manifolded together. In either case ON-OFF, power availability, flow, pressure, and alarm functions are usually provided.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 228.

4.8L List the activities that are usually instrumented or controlled in the anaerobic sludge digestion process.

4.8M Under what circumstances would digested sludge flow be recorded?

4.8N How are temperatures measured in an anaerobic sludge digester?

4.8O What is the purpose of digester transfer and recirculation pumps?

4.9 ROUTINE MAINTENANCE AND TROUBLESHOOTING

So far we have discussed how instruments and controls work and how they are used in treatment plant process control. Next we will discuss what the operator's role is in maintaining and troubleshooting the instruments and controls. As we have already pointed out, though, unless the operator is qualified, the repair of most types of instruments should be assigned to a specialist in the field. There are many practical and important things an operator can and must do to keep the system operating efficiently.

First, it is important for the operator to recognize that like other equipment in a treatment plant, instruments and controls need attention such as cleaning, adjusting, calibrating, repairing and/or replacement from time to time. In most cases, instruments and controls are more fragile than other pieces of treatment plant equipment and must be given appropriate care whenever handled.

Before we begin routine maintenance or troubleshooting the instruments and controls, it is essential that the operator be familiar with the process and the instrumentation and/or controls used to control the process. If you don't know what you're doing, leave it alone and request assistance!

A routine maintenance program will minimize instrument and control failures. The routine maintenance program should be a written, prescribed procedure defining what the operator is responsible for and what the instrument specialist is responsible for and who will do what and when. Each plant with its different processes, instruments, controls and people will have a unique routine maintenance program. The maintenance program should provide for a file on each instrument and control system. Date of purchase, date of installation, installer, make, and model-serial numbers should all be recorded, along with any maintenance manual, or technical specifications supplied with the equipment. Provisions for on-the-job and off-the-job training should be sought whenever possible.

Based on the manufacturers' recommendations and plant experience, spare parts, plus any special tools should be purchased ahead of time and properly stored. Whenever possible, appropriate areas for instrument maintenance and storage should be dedicated for this purpose; areas with high humidity and corrosive gases are to be avoided.

Before troubleshooting for instrument and control failures, the operator must make certain that the difficulty is truly due to defective instrumentation or control and not due to some quirk in operations. There have been cases where so-called instrument failures have been traced back to simple things like unplugged power supplies, the pneumatic air receiver left out of service after being drained of water and similar types of minor problems.

Before starting work on the system, safety precautions must be observed, such as unplugging electrically connected instruments and controls. Even though they may be low voltage, there is always the possibility of shock to the operator and/or damage to the equipment. Also, care must be exercised when handling toxic materials such as mercury or flammable material such as alcohol which could be encountered when working with manometers. Care also must be exercised with certain types of density meters that use a radioactive cell which by law can only be handled by an appropriately licensed technician. Such devices are required to be identified and labeled accordingly.

Additional precautions must be observed whenever you intend to work on or remove instruments and controls directly attached to live or operating processes. For example, before you remove a pressure gage from an air or water line, be sure that the service has been turned off. Before you turn the service off, be sure it will not adversely affect the system or someone else.

In other words, be sure that others are advised of your intended scope of work. They must be notified or warned of what you are going to do, when you are going to do it, how long it will take, and what will be affected. Therefore, just like any other piece of plant equipment, instruments and controls being worked on should be "tagged-out". This will advise others that the instruments and controls are out of service and must not be used.

The "tagged-out" instruments and controls (Fig. 4.33) must also be "logged" in the shift or daily operations log book. You must note alarm functions that are out of service, so that other means may be used to detect out-of-limit conditions. The use of "Good Communications" and "Common Sense" will avoid a lot of unnecessary "Headaches."

Table 4.2 contains some guidelines on what maintenance and trouble-shooting duties an operator can generally perform.

OUT OF ORDER

Fig. 4.33 "Tagged-out" controls

TABLE 4.2 MAINTENANCE AND TROUBLESHOOTING DUTIES

Instrument - Device	**Maintenance - Service by the Operator**
1. *THERMOMETERS*	
Liquid or Capillary	1. Check for leakage or breakage 2. Clean off surface 3. Replace with spare
Bimetallic	1. Clean sensing surface 2. Replace with spare
Thermocouples	1. Check for loose connections, corrosion, or damaged insulation, and repair as necessary
2. *PRESSURE GAGES*	
Manometer	1. Clean and/or add fluid 2. Check and tighten connections
Bourdon Tube, Diaphragm or Bellows	1. Check for sticking or damage 2. Replace with spare
3. *LEVEL INDICATORS*	
Float	1. Clean float 2. Check and clean cable and pulley; lubricate as necessary
Probes Electric Capacitance Ultrasonic	1. Check and clean connections 2. Clean probe if possible 3. Check power supply (fuse)
Bubbler Tube	1. Check air supply 2. Check air tube and clean
Diaphragm Box or Sight Tubes	1. Clean
4. *DENSITY METERS*	
Optical Ultrasonic Radioactive	1. Clean (flush) sensors with water 2. Check "zeroing" with water 3. Check power supply (fuse)
5. *RPM INDICATOR TACHOMETER*	
Cable Drive	1. Check cable, clean, lube, tighten
D.C. Generator	1. Check terminal connections 2. Check drive coupling
Strobe	1. Check battery or power supply 2. Check for burned out bulb
Pulse Detector	1. Check terminal connections 2. Check pulse sensor clearance
6. *VISUAL READ-OUTS*	
Circular or Strip Chart	1. Change charts 2. Check for irregular movements 3. Check power supply
Pens	1. Clean pen 2. Refill or replace ink cartridge
7. *METERS*	(Also see Chapter 15, Section 15.4, "Flow Measurements - Meters and Maintenance," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS*)
Venturi	1. Check purge water 2. Check flow zero 3. Clean taps with bayonet, if appropriate
Orifice Plate	1. Check flow zero 2. Clean taps with bayonet, if appropriate
Magnetic	1. Check flow zero 2. Check power supply
Weirs	1. Clean weir face 2. Check level indicator
8. *ALARM FUNCTIONS - HIGH TEMPERATURE, PRESSURE & LEVEL*	
Lights	1. Test bulb, change as necessary
Audible Signal	1. Test for sound
9. *CONTROLLERS*	
Pneumatic	1. Check for air supply availability
Electronic	1. Check for power availability
Timers	1. Check to see that they are working
Auto Manual	1. Switch from one mode to the other, to see that they work
10. *INTEGRATORS*	
Mechanical or Electrical	1. Check power supply
11. *OTHER INSTRUMENTS*	
LEL Probe	1. Check zero setting 2. Check alarm function 3. Test with gas, if appropriate
DO Probe	1. Clean probe 2. Check for loose connections
pH Probe	1. Clean probe 2. Check electrolyte
Turbidimeter	1. Check meter zero
CH_4 or CO_2 Analyzer	1. Check for gas supply 2. Check for power supply
OTHER CONTROLS - INDICATORS	
On-Off Lights	1. Test bulbs
Percent Open-Closed	1. Manually check indicator against valve opening

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 228.

4.9A What kind of attention do instruments and controls require?

4.9B What information should you provide other operators before you start to work on an instrument or control?

4.10 ADDITIONAL READING

1. *PROCESS INSTRUMENTATION AND CONTROL SYSTEMS*, MOP OM-6. Publications Order Department, Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314. Order No. MOM60H0. Price $24.00 to members; $32.00 to others.
2. *INSTRUMENTATION FOR WASTEWATER TREATMENT SYSTEMS*, by J.S. Samkoff, Technical Reprint IW-113, Graver Water, Division of the Graver Company, 2720, U.S. Highway 22, Union, New Jersey 07083.
3. *AUTOMATION AND INSTRUMENTATION*, M-2, AWWA Computer Services, American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235. Order No. 30002. Price $18.00 to members; $23.00 to others.
4. *WASTEWATER TREATMENT PLANT INSTRUMENTATION HANDBOOK*. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Order No. PB 86-108 636/AS. Cost $30.95.

26.11 ACKNOWLEDGMENT

Material in this chapter was reviewed by Norman Ole Thompson.

END OF LESSON 4 OF 4 LESSONS ON INSTRUMENTATION

Please answer the discussion and review questions before working the objective test.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 4 of 4 Lessons)

Chapter 4. INSTRUMENTATION

Please write the answers to these questions in your notebook before continuing with the objective test. The problem numbering continues from Lesson 3.

16. Why are accurate air flow measurements very important in the activated sludge process?
17. How is the air compressor speed in RPM measured?
18. What precautions should be taken to ensure accurate dissolved oxygen readings in aeration tanks?
19. A low level alarm in a sludge digester could indicate what types of problems?
20. Why must the digester gas pressure be monitored in fixed cover digesters?
21. Where should combustible gas alarms be installed?
22. What special safety hazards may be encountered when maintaining and troubleshooting instruments and controls?

PLEASE WORK THE OBJECTIVE TEST NEXT.

SUGGESTED ANSWERS

Chapter 4. INSTRUMENTATION

Answers to questions on page 182.

4.0A Plants are being designed and constructed with sophisticated instrument and control systems because of tougher discharge and monitoring requirements and also to help operators do their job.

4.0B An instrument is a measuring device.

4.0C A control is a device or series of devices that effect some change due to some other change in conditions.

Answers to questions on page 186.

4.0D Instruments are used in place of or to assist the operator's sense of sight, smell, touch and hearing because of the need for:

1. Accuracy of the measurement,
2. Repeatability of the measurement,
3. Sensitivity of the measurement, and
4. Permanence of the measurement.

4.0E The sensitivity of a measurement is the ability to measure the smallest or largest value necessary.

4.0F An instrument's accuracy depends on the preciseness or exactness of the measurements. Repeatability is the ability of an instrument to measure something again and obtain the same answer that resulted previously.

Answers to questions on page 190.

4.1A Instruments are used instead of our human senses because they provide a more accurate, consistent, sensitive and permanent means of monitoring (measuring) treatment processes.

4.1B Instruments measure temperature, pressure, flow, level, density, velocity and analytical measurements (physical, chemical and biological).

4.1C Flow can be defined as a "flow rate" (volume passing a point at any given instant or time period) or as a "total flow or volume" (total volume passing a point within a specified time period).

Answers to questions on page 195.

4.2A Typical units of measurement for the listed parameters in both English and metric units.

Parameter	English	Metric
1. Temperature	°F or °R	°C or °K
2. Pressure	psi or psf in. H_2O or Hg	kg/sq cm or kg/sq m cm H_2O or Hg
3. Flow		
Liquids (volume)	cfs, GPM or MGD	*L*/s or cu m/s
Gases (volume)	cfm	cu m/s
Solids or Liquids (weight)	lb/hr	g/s
Solids (volume)	cu ft/day or cu yd/day	cu m/day
4. Level	in. or ft	cm or m
5. Density	lbs/cu ft	kg/cu m
6. Velocity		
Linear	ft/sec or ft/hr	m/sec or m/hr
Rotational	RPM	RPM

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 206.

4.3A Three different types of temperature measuring instruments or sensors are:

1. Liquid filled thermometer,
2. Bimetallic thermometer, and
3. Thermocouple.

4.3B The most common liquids used in manometers to measure pressures are water and mercury.

4.3C

Known	Unknown
Density of Water = 62.4 lbs/cu ft	Pressure, psi, if manometer reads: 1. 8 inches of water 2. 8 inches of mercury
Specific Gravity of Mercury = 13.55	

1. Determine pressure in psi if manometer reads 8 inches of water.

$$\text{Pressure, psi} = \text{Density, lbs/cu in} \times \text{Height, in}$$

$$= \frac{62.4 \text{ lbs/cu ft} \times 8 \text{ in}}{1728 \text{ cu in/cu ft}}$$

$$= 0.29 \text{ psi}$$

2. Determine pressure in psi if manometer reads 8 inches of mercury.

$$\text{Pressure, psi} = \text{Density, lbs/cu in} \times \text{Height, in}$$

$$= \frac{13.55 \times 62.4 \text{ lbs/cu ft} \times 8 \text{ in}}{1728 \text{ cu in/cu ft}}$$

$$= 3.91 \text{ psi}$$

Answers to questions on page 206.

4.4A The purpose of transmitting instruments is to send the variable, as measured by the measuring device (sensor), to another device for conversion to a usable number.

4.4B The different types of receivers include indicators, recorders, totalizers (integrators) and multipurpose.

Answers to questions on page 209.

4.5A The five common parts to a control system are:

1. Primary element or sensor,
2. Transmitter,
3. Measuring element or receiver,
4. Controlling element, and
5. Final element.

4.5B The common types of control methods include:

1. Open and closed loops,
2. Manual control,
3. On-off control,
4. Proportional control,
5. Proportional control with reset, and
6. Proportional control with reset derivative.

Answers to questions on page 211.

4.6A The purpose of recorders is keeping continuous and permanent records of process variables.

4.6B The two basic types of recorders found in treatment plants are circular charts and strip charts.

4.7A Integrators or totalizers are used in treatment plants to sum up the amount of liquid or gaseous flow.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 215.

4.8A The preliminary treatment section could contain instrumentation monitoring and/or controlling the following functions:

1. Influent Level (high-low levels)
2. Influent Flow (rate)
3. Explosive Gas Detection (hydrocarbon, LEL)
4. Bar Screen Operation (On-Off)
5. Grit Removal (On-Off)
6. Ventilation System (On-Off)
7. Valves and Gates (Closed, percent Open)
8. Sump Pump (On-Off)
9. High Water Alarm

4.8B The influent level is an important indicator of the rate of inflow. The number of bar screens or grit channels on-line depends on the inflow rate. Abnormally low flows could indicate an obstruction in the influent sewer line or, worse yet, failure of the sewer pipe. A high water alarm could indicate a blockage at the bar screens or perhaps only a partially opened valve or gate hindering the flow downstream.

4.8C Gasoline or other petroleum products can be detected in a wet well by using an explosive or combustible gas detection instrument. This instrument may or may not be useful in detecting hydrocarbon concentrations which affect treatment, but it is necessary for safety reasons with regard to explosive gases and vapors.

4.8D Wet well ventilation systems must be kept operating continuously both for the operator's safety and for minimizing the accumulation of concentrations of moist or otherwise corrosive and toxic gases.

Answers to questions on page 217.

4.8E Instrumented activities that could concern an operator in primary treatment include:

1. Collector drive motor,
2. Flights,
3. Grease skimmers,
4. Sludge blanket depth,
5. Sludge pumps,
6. Sludge draw-off valve,
7. Sludge flow,
8. High water alarm, and
9. Water level control valve.

4.8F Flight movement can be detected by:

1. A pivoted stick moving every time a flight strikes it, or
2. An ultrasonic signal which is reflected by a passing flight.

4.8G Sludge pumps can be controlled or regulated by:

1. Turning the pumps on and off,
2. Using a timer control, and
3. Using a sludge density meter control.

4.8H Butterfly valves are used to control the flow to each primary tank to equalize the flow and promote the most efficient use of tanks in service.

END OF ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 220.

4.8I Air flow is usually measured by a differential pressure metering device such as an orifice plate.

4.8J Air pressure gages are usually placed at the air compressors and also downstream at main aeration lines.

4.8K Oil levels in air compressors may be measured manually by a dip stick, read from a sight glass or by the use of electronic or ultrasonic systems.

Answers to questions on page 223.

4.8L Activities that are usually instrumented or controlled in the anaerobic sludge digestion process include:

1. Raw sludge feed controller,
2. Digester tank level and alarms,
3. Digester sludge flow,
4. Digester gas flow,
5. Digester gas pressure,
6. Digester sludge temperature,
7. Digester heating system (steam, hot water),
8. Digester transfer and recirculation pumps,
9. Digester gas quality,
10. Combustible gas alarm, and
11. Digester gas mixing compressor.

4.8M Digested sludge flow would be recorded if the sludge receives additional treatment, such as dewatering or chemical conditioning.

4.8N Temperatures in an anaerobic sludge digester may be measured by:

1. A built-in temperature-sensing device such as a thermocouple,
2. Manually placing a thermometer in sludge running into the sample sink.

4.8O Digester transfer and recirculation pumps are used to mix the digester contents, transfer sludge between digesters, pump out digested sludge and pump supernatant or plant effluent in or out of digesters.

Answers to questions on page 226.

4.9A Instruments and controls need attention such as cleaning, adjusting, calibrating, repairing and/or replacement from time to time.

4.9B Before starting to work on an instrument or control, notify other operators what you are going to do, when you are going to do it, how long it will take, and what will be affected.

END OF ANSWERS TO QUESTIONS IN LESSON 4

OBJECTIVE TEST

Chapter 4. INSTRUMENTATION

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one answer to each question.

1. One of the most sophisticated and common control systems is the human body.
   1. True
   2. False
2. A control system is a measuring device.
   1. True
   2. False
3. Repeatability means measuring something over and over again until you get the same answer twice.
   1. True
   2. False
4. Gage pressure does not take into consideration the weight of the atmosphere above the earth.
   1. True
   2. False
5. A manometer with a vertical leg is more sensitive than a manometer with an inclining or sloping measuring leg.
   1. True
   2. False
6. In a control system, the final element is the device that controls the energy supplied to the process being controlled.
   1. True
   2. False
7. A recorder is a device that records information onto a sheet of paper that is moving at a specific speed.
   1. True
   2. False
8. In large treatment plants, all digesters are loaded at the same rate to evenly balance the digester loadings.
   1. True
   2. False
9. If you don't know how to maintain or troubleshoot instruments and controls, leave them alone and request assistance.
   1. True
   2. False
10. Special areas should be designated for instrument maintenance and storage and areas with high humidity and corrosive gases should be avoided.
    1. True
    2. False
11. Which of the following are measuring devices?
    1. Bathroom scale
    2. Computer
    3. Heater
    4. Ruler
    5. Thermometer

Questions 12, 13, and 14. In the human body the eyes are the (12) __________ the nervous system is (13) __________ and the brain is the (14) __________.

Answers to questions 12, 13, and 14.

1. Control logic
2. Indicator
3. Probe
4. Sensing instrument
5. Transmission system

15. The operation of a toilet bowl flush tank is an example of what type of control system?
    1. Biological and cybernetic
    2. Cybernetic and electrical
    3. Electrical and hydraulic
    4. Hydraulic and mechanical
    5. Mechanical and pneumatic
16. What method or device should you use to measure the diameter of a replacement pump shaft?
    1. Engineer's scale
    2. Metallic tape
    3. Micrometer
    4. Ruler
    5. Surveyor's chain
17. Temperature can be measured on which of the following scales?
    1. Celsius
    2. Fahrenheit
    3. Joule
    4. Kelvin
    5. Pascal
18. Common types of pressure gages include
    1. Bellows.
    2. Bourdon.
    3. Diaphragm.
    4. Parshall.
    5. Venturi.
19. Liquid levels may be measured by
    1. Bubbler tubes.
    2. Floats.
    3. Probes.
    4. Sight tubes.
    5. Ultrasonic sounds.

20. A tachometer measures
    1. Density.
    2. Distance.
    3. Rotational velocity.
    4. Temperature.
    5. Time.

21. The primary element in a control system is also called a
    1. Controller.
    2. Receiver.
    3. Recorder.
    4. Sensor.
    5. Transmitter.

22. The set point is the position at which the ____________ is set.
    1. Controller
    2. Receiver
    3. Recorder
    4. Sensor
    5. Transmitter

23. Different types of control systems include
    1. Manual.
    2. On-Off.
    3. Project.
    4. Proportional.
    5. Ratio.

24. Abnormally low flows into a treatment plant could indicate
    1. A broken sewer pipe.
    2. A downstream blockage.
    3. A failure in the sewer system.
    4. An industrial waste discharge.
    5. An obstruction in the sewer.

25. What types of alarm systems are usually installed on grit channel equipment?
    1. Collection drive system on or off
    2. Explosive gas detection
    3. High water level
    4. Motors tripped-out on overload
    5. Oxygen deficiency

26. Sludge blanket depths may be measured by use of
    1. Bubbler tubes.
    2. Floats connected to cables and pulleys.
    3. A hose and an aspirator.
    4. Pressure gages.
    5. Ultrasonic transmitters and receivers.

27. Primary sludge flow is usually metered by
    1. A magnetic flow meter.
    2. An orifice.
    3. A Parshall flume.
    4. A Venturi meter.
    5. A weir.

28. Excessive air compressor lubrication oil temperatures may indicate
    1. Heater malfunction.
    2. High oil levels.
    3. Inoperative oil coolers.
    4. Low oil levels.
    5. Motor overload.

29. Which of the following factors are usually measured by air compressor vibration sensing devices?
    1. Acceleration
    2. Displacement
    3. Flow
    4. Time
    5. Velocity

30. A high level alarm in a sludge digester could indicate
    1. A control system malfunction.
    2. A digested sludge valve left open.
    3. An inoperative digested sludge withdrawal system.
    4. A plugging of the overflow.
    5. A possible leak or break somewhere in the system.

31. Digester gas flows are commonly measured by the use of
    1. Orifice plates.
    2. Positive displacement meters.
    3. Rotameters.
    4. Turbine meters.
    5. Venturi meters.

32. Which of the following maintenance services can be performed by operators on Venturi meters?
    1. Check flow zero
    2. Check level indicator
    3. Check power supply
    4. Check purge water
    5. Clean taps

33. Which of the following maintenance services can be performed by operators on LEL meters?
    1. Check alarm function
    2. Check electrolyte
    3. Check zero setting
    4. Check probe
    5. Test with gas

● END OF OBJECTIVE TEST ●

CHAPTER 5

INDUSTRIAL WASTE MONITORING

by

Larry Bristow

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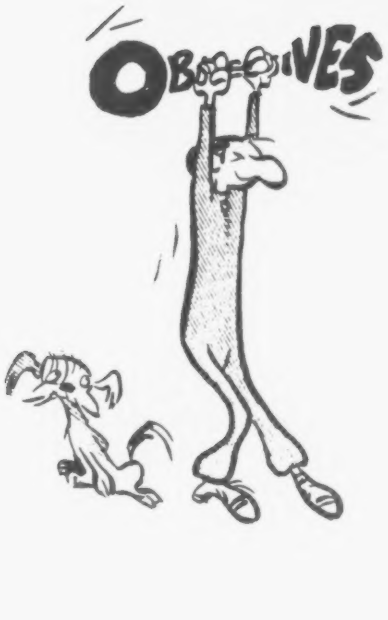
OBJECTIVES

Chapter 5. INDUSTRIAL WASTE MONITORING

Following completion of Chapter 5, you should be able to do the following:

1. Develop an industrial waste monitoring program,
2. Justify an industrial waste monitoring program,
3. Administer and manage the program,
4. Locate sources of industrial waste discharges,
5. Collect and preserve representative samples,
6. Document the "chain of possession" of your sampling program,
7. Develop a monitoring strategy, and
8. Conduct your duties in a safe manner.



GLOSSARY

Chapter 5. INDUSTRIAL WASTE MONITORING

COMPOSITE (PROPORTIONAL) SAMPLE
(com-POZ-it)
COMPOSITE (PROPORTIONAL) SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

GRAB SAMPLE
GRAB SAMPLE

A single sample of wastewater taken at neither a set time nor flow.

PERISTALTIC PUMP (peri-STALL-tick)
PERISTALTIC PUMP

A type of positive displacement pump.

REFRACTORY MATERIALS (re-FRACK-tory)
REFRACTORY MATERIALS

Materials difficult to remove entirely from wastewater such as nutrients, color, taste- and odor-producing substances and some toxic materials.

REPRESENTATIVE SAMPLE
REPRESENTATIVE SAMPLE

A portion of material or water identical in content to that in the larger body of material or water being sampled.

SLUGS
SLUGS

Intermittent releases or discharges of industrial wastes.

TRUNK SEWER
TRUNK SEWER

A sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population.

CHAPTER 5. INDUSTRIAL WASTE MONITORING

(Lesson 1 of 2 Lessons)

5.0 NEED FOR INDUSTRIAL WASTE MONITORING

The rapid advance of industrial technology has added new concerns for the wastewater treatment field. Chemical compounds of increased complexity and quantities are being discharged into the sewers. The impact of these waste discharges on treatment processes is harmful in some cases and unknown in others. This, coupled with increased knowledge of the effects of these chemicals on health and the environment, creates new or additional problems for many treatment plant operators. This chapter will discuss the problems associated with, and methods of regulating, industrial waste discharges. For information on actually treating industrial wastes, see Chapter 2, "Activated Sludge," and Chapter 6, "Industrial Waste Treatment."

5.00 Objectives of Industrial Waste Monitoring

Several chapters in this course discuss shock loads and how to minimize their effects. Industrial wastes often cause that shock load. A program for monitoring and regulating industrial discharges is essential to:

1. Prevent serious shock loads and thus assure that no disruptions of plant processes occur,
2. Provide physical protection of personnel and facilities,
3. Prevent discharge of pollutants from treatment plants, and
4. Provide a data base for fair and reasonable sewer-use charges and for engineering data.

5.01 Importance of a Monitoring Program

A discharge of industrial wastes may affect a treatment plant to the extent that it fails to meet the discharge requirements set by the NPDES permit, the regulating agency, or other authority. One cause for the failure may be a process upset occuring due to toxic materials that destroy or affect the metabolism of microorganisms that are part of the treatment process. Another cause may be toxic materials that pass through the treatment process and are present in the plant effluent. Hydraulic overloads can upset treatment processes by "washing out" the microorganisms in the treatment process. Solids carry-over to the effluent will result from a process upset, as will odors resulting from upset biological treatment processes.

Industrial discharges may cause problems in both the collection system and treatment plant including excessive solids that may cause stoppages, corrosive substances that may damage the pipes, and flammable materials that may cause fires or explosions. Dangerous gases may result from some discharges. In some cases, the gases will cause an oxygen deficiency. In others, toxic gases such as hydrogen sulfide or cyanide may be present. Additionally, some gases may create flammable or explosive conditions.

5.02 Objectionable Characteristics of Industrial Wastes

Some undesirable properties and effects of various industrial waste discharges are presented in this section.

Possible Collection System Problems:

1. Acid and Alkali Wastes - cause corrosion of pipes.
2. Thermal Wastes - hot discharges raise the temperature of the wastewater, speeding up decomposition and thus causing septic conditions. Septic conditions can produce odor and corrosion problems as well as toxic, flammable, explosive and oxygen-deficient atmospheres.
3. Solids - excessive solids may settle and cause stoppages and septic conditions.
4. Oils and Greases - build up on pipe walls, reducing capacity and causing stoppages and septic condtions.
5. Odors - the discharge itself may be odorous, or the odors may result from the conditions caused by the discharge.
6. Toxic Substances - may include infectious wastes, poisons (such as pesticides) or gases (such as cyanide or hydrogen sulfide).
7. Flammable and Explosive Materials - includes fuels, paint thinners, and hydrogen sulfide.

NOTE: Hydrogen sulfide results from septic conditions. Hydrogen sulfide will cause odors, corrosion, and can be flammable under certain conditions and toxic to your respiratory system.

Possible Treatment Plant Problems:

1. Organic Overloads - more suspended and dissolved solids than the plant can handle.
2. Toxic Substances - (see previous section on collection systems).
3. Oils and Greases - may flow through plant and form surface scums on receiving waters (see previous section on collection systems).
4. Acids and Alkalies - cause corrosion of pipes and can be toxic to organisms in treatment processes.
5. Hydraulic Overloads - reduce detention or treatment times and cause incomplete treatment of wastes.
6. Refractory Materials - materials that are not removed by plant processes, such as nutrients, color, taste and odor producing substances, and some toxic materials.
7. Hazardous Wastes - solvents, fuels, corrosives, poisonous substances, infectious wastes, radioactive wastes, gases (explosive, toxic or oxygen-displacement).

Thus, it is possible for a seemingly harmless food-processing plant waste, for example, to discharge excessive solids and organic materials and cause intolerable conditions in the collection system and a wastewater treatment plant.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 259.

5.0A What are the objectives of an industrial waste monitoring program?

5.0B List the adverse characteristics of industrial wastes that could seriously impact on (1) collection systems and (2) treatment plants.

5.1 ADMINISTRATION OF A MONITORING PROGRAM

5.10 Organization

The U.S. Environmental Protection Agency (EPA) requires monitoring programs that control problems at their sources. State agencies also have monitoring requirements. In some cases, they may be more stringent than the basic EPA regulations. In order to abide by these regulations and achieve the objectives listed in Section 5.00, certain actions will be necessary. Essential actions include the building and maintenance of a data base and the establishment and enforcement of effective local ordinances regulating industrial discharges.

5.11 The Data Base

A file should be established and maintained on each discharging industry. The technical data contained in the file is essential for making decisions in areas such as operation and maintenance of treatment plant processes, program monitoring, and engineering design of facilities. The following information should be included in each discharger's file.

1. Industry Identification. Name of firm, products or services provided, raw materials or chemicals used, and a brief description of manufacturing and treatment processes used (e.g., batch, continuous, seasonal).[1]
2. Flow Data. Characteristics of the wastewater discharge including flow patterns (peaks and lows), total volume, and BOD, suspended solids, pH, and other critical characteristics.
3. Laboratory Results. Dates, times, and results of laboratory tests on discharges.
4. Billing Information. Calculations used to establish billing rates.
5. Treatment Information. Pretreatment measures used by the industry and any special measures that must be taken by the treatment plant.
6. Reports of Unusual Circumstances or Incidents. Data on spills, product or process changes, or changes in pretreatment efforts by the industry.
7. Industrial Facilities. Layout of the industrial site showing location of sewer lines and connectors, chemical storage areas, spill protection measures provided, monitoring facilities, and location of person to contact upon arrival for inspection visit.
8. Emergency Information. Names and phone numbers of at least two persons with the industry who have authority to take appropriate action in case of accidents or spills.

5.12 Enforcement

A good sewer-use ordinance is the proper tool to provide the necessary authority to control industrial wastes. The objectives of the ordinance are to provide for the control of industrial discharges to the degree that (1) no harm is done to personnel or wastewater collection and treatment facilities, and (2) that these discharges do not cause the wastewater treatment plant to violate its discharge requirements. Also, it should provide for equitable sewer service charges.

There are several specific powers that should be authorized in a sewer-use ordinance.

1. Inspecting and monitoring.
2. Requiring pretreatment and/or flow adjustment.
3. Curtailing or ceasing of discharge.
4. Requiring spill protection measures.
5. Issuing permits to dischargers.

   Regulatory agencies usually will require the local agency to use a permit system. This is a good mechanism for inspections and gathering base information. A sample copy of an Industrual Sewer-Use Permit Application is located in Appendix A.
6. Billing for sewer service charges.
   a. Normal sewer-use charges.
   b. Special charges and/or fines for damages caused by spills.

   Billing rates should be fair and equitable for everyone. Charges to industry for treating flows, including BOD and suspended solids, should be similar to the charges to businesses and homeowners. Sufficient funds should be collected from all dischargers to cover all of the operating and maintenance costs of the wastewater collection and treatment facilities. Fines and extra charges for accidental spills, dumps or additional loadings should be greater than the extra costs associated with resulting problems and a poor plant effluent in order to discourage future problems resulting from negligence.

---

[1] *EPA's Standard Form A (see Appendix C) may be used for this purpose. This form includes a space for the standard industrial classification code number of the industry involved. The code numbers are published by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The stock number of the book is 041-001-00314-2, price is $24.00 and the title is "Standard Industrial Classification (SIC) Manual 1987." Use of these code numbers if often mandatory. (NOTE: Many industries will fit into two or more classifications. The EPA Form A (Appendix C) provides only for the "major" product or service. This is not adequate for monitoring purposes. In these cases, more than one Form A per industry, or special forms will be needed.)*

A sample ordinance, prepared by the Environmental Protection Agency (EPA), is included in Appendix B.

5.13 Dealing with Industry

Your personal contact with industry representatives can be crucial. You have the authority to seriously affect their operations. However, you must obtain their cooperation. Good communications are a must. If you are going to require an action or response to a problem on the part of an industry, first be sure that you can show the need for the action. Most people will cooperate fully if they are convinced that a real need exists.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 259.

5.1A Why is a good data base on industrial waste discharges important?

5.1B What information should be collected to develop a data base?

5.1C A sewer-use ordinance provides authority for what enforcement activities?

5.2 HOW TO MONITOR DISCHARGES

Monitoring is the key to industrial waste control. There must be a program of surveillance to assure compliance with prescribed limits. In the larger cities with heavy industrial areas, self-monitoring by the industries, with spot-checks by the local agency, is usually practiced. Smaller communities may do their own monitoring, or at least a part of it.

5.20 Monitoring Programs

5.200 Self-Monitoring

Self-monitoring by industry is common in large industrial areas. The burden of monitoring a large number of industries otherwise would be overwhelming to a local agency. Self-monitoring may be used where the industry has laboratory facilites or access to a commercial laboratory. The laboratories used should be certified by the appropriate health department or regulatory agency.

Routine inspections should be made, as well as examination of regular reports received from the industry. In addition, random sampling (with the samples analyzed at a different laboratory) should be done to confirm the results of the self-monitoring program. When this is done, the sample should be split so both laboratories might analyze it. This will bring to light any variations in procedure between the laboratories. When making inspections, be sure to abide by all of the security and safety procedures of the firms or companies being inspected.

5.201 Continuous Monitoring

Special sensors are available for continuously monitoring a number of water quality indicators. The most commonly used ones are for temperature, pH, and specific conductance. In some cases, frequent cleaning and calibration of the special sensors will be necessary.

There is considerable research being done in the field of continuous monitoring. A broader range of water quality indicators and increased reliability may be expected in the future.

5.21 Monitoring Provisions

Suitable provisions must be provided for monitoring industrial wastes. In most cases, this is done by industry. For monitoring purposes, a flow meter frequently must be installed. While water meter data can be used to determine total flow in some cases, this does not provide peak flow data. A good sampling location is required, with possible locations ranging from a special manhole to complete monitoring structures.

5.22 Need for Representative Samples[2]

As is true in sampling for treatment plant process control, good sampling of industrial wastes is both difficult and of the utmost importance. The sample should be representative; that is, it should be an accurate representation of the entire wastewater discharge. This is essential if you are to know the actual characteristics of the discharge. No matter how highly trained the laboratory technicians or how sophisticated their equipment, their work can be no better than the samples that have been collected for analysis. Very often a great deal of emphasis is placed on the accuracy of the laboratory analyses, with only casual attention given to obtaining the samples. The collection of samples must be carefully thought out and performed by responsible, trustworthy individuals. Representative samples of slug discharges of chemicals or wastes from industrial plants are difficult to obtain even when you know the time of discharge.

5.23 Sampling Points

A good sampling point is one that is easily accessible and may be located anywhere that a representative sample of the industrial wastewater discharge may be obtained. Remember that you are sampling only the flow from one industrial waste discharger and not the total flow in a municipal collection system. This usually involves a special manhole or monitoring structure.

The special manhole may simply be an ordinary manhole that is easily accessible. The manhole may have a measuring weir or flume. Where continuous monitoring of certain water quality indicators (such as pH) is needed, a special monitoring station may be necessary. The station would house the monitoring equipment, which would typically be a flow meter, sampler, refrigerator, and pH or other special monitoring equipment. Sometimes the monitoring station is equipped with an alarm system and provisions to stop or divert the discharge to a holding tank or pond. For example, a pH probe is installed to monitor the discharge from an industry. An accidental spill in the plant produces a discharge with a pH of 4.7. If the minimum pH was 6.0, an alarm would sound. Downstream from the probe a flow diversion device would divert the discharge to a holding basin or to a pretreatment facility to neutralize the discharge. Other facilities in a sampling station may include a sink and a small workbench.

The sampling point needs to be located where the wastewater flow from the industrial plant is well mixed and before the flow is discharged into the public sewer. Flat, sluggish areas are poor sampling locations because solids will tend to settle to the bottom. Under these circumstances, the sample may contain too many or too few solids, depending on the manner in which the sample was collected. Solids also may settle out upstream from weirs. Bubbling air through the wastewater stream has been used for mixing in channels and above weirs. The solids-settling problem is reduced when flumes are used as primary measuring devices.

---

[2] *Representative Sample. A portion of material or water identical in content to that in the larger body of material or water being sampled.*

Where oil or other similar material is floating, representative sampling is very difficult. If it is possible to divert the entire waste stream to a large container for a short time period, the approximate quantity of floatables or oil may be determined by measuring the material that rises to the top of the container.

If the industry has two or more outlets that discharge process waste into the sewer, the monitoring problem is compounded. If possible, the outlets should be combined into one discharge. Otherwise, separate facilities will be required on each discharge.

QUESTIONS

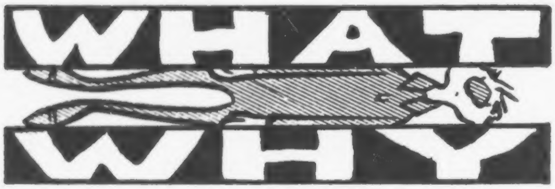
Write your answers in a notebook and then compare your answers with those on page 259.

5.2A Why are self-monitoring programs commonly used in large industrial areas?

5.2B What type of maintenance may be needed for the sensors used in continuous monitoring programs?

5.2C Define the term "representative sample."

5.2D Where or under what conditions would you attempt to collect a representative sample?



5.24 Types of Samples

5.240 Grab Samples[3]

The simplest and least expensive sampling method is the grab sample. However, grab samples are not useful for discharges that vary in makeup (constituents) or quantity. This is particularly true when the samples are being taken for billing purposes. Grab samples can be useful for qualitative analyses to determine if particular materials (e.g., heavy metals that must be preserved so they won't precipitate out) are present. The grab sample should be obtained from the center of the wastewater flow.

To determine the peak concentration and time of occurrence of a toxic waste discharge, collect grab samples hourly or use a composite sampler that collects samples at regular time intervals and does not mix the samples. Analyze the individual samples — do not mix them.

5.241 Composite Samples[4]

Composite samples will provide the most accurate representation of a wastewater stream that can be obtained at a reasonable cost. The simplest method of preparing a composite sample is by taking grab samples at predetermined times, either by hand or through a clock-controlled sampler. The principal objection to these timed grab samples is that the sample quantities are the same for high and low flow periods. This can be overcome if the samples are stored in individual bottles, and then proportionally combined based on ratios from a flow meter chart. A limitation of composite samples is that an isolated or peak discharge of a concentrated toxic waste could be diluted by the other samples taken during the sampling period.

Automatic flow-proportional sampling is the standard method for obtaining representative samples. In this method, the sampler is activated by a flow meter. A sample is collected for each pre-selected quantity of flow (e.g., one sample for each 10,000 gallons).

This results in more frequent samples during periods of high flow. Other flow-proportional sampling systems use uniform timing and vary the quantity of sample according to the flow.

Various methods are used to obtain the samples. Scoops, conveyors with small "buckets" attached, vacuum chambers, and small pumps are the most common. Some samplers obtain the sample directly from the wastewater flow. In others a pump supplies a constant stream of the wastewater to the samplers, with an overflow line carrying the excess back to the sewer. Figure 5.1 shows a sampling device, a peristaltic (a type of positive displacement pump) pump sampler.

Flow proportional samplers usually are installed in permanent monitoring facilities. Most of these samplers combine the various samples in a refrigerated compartment. This prevents deterioration and change of the samples.

5.25 Portable Equipment

Samplers, flow meters and some instruments, such as pH meters and conductivity meters, are available for field work. Portable flow meters use a weir or Palmer-Bowlus flume for easy installation in a sewer line. The meters themselves use floats, air or nitrogen bubbling, built-in electronic sensing, motor-operated sensing probes, or sonar for sensing the water level behind the weir or in the measuring flume. Recording charts and totalizers usually are part of the equipment so that a record of the flow is obtained. (Portable flow meters and recorders are shown in Figure 5.2.)

Most portable samplers use peristaltic pumps or vacuum chambers to pick up the samples (Figures 5.1 and 5.3). Power is supplied by rechargeable batteries or, when possible, from a 110-volt AC line using a "power-pack" which fits the same space usually occupied by the battery.

The pumping rate must be considered when a sample is collected. A velocity of 2 to 5 feet per second (0.6 to 1.5 m/sec) in the sampler suction tubing produces repeatable results. Lower velocities tend to leave solids behind in the tubing, while higher velocities may pull in large chunks of material, yielding erratic results in the data.

---

[3] *Grab Samples. Single samples of wastewater taken at neither a set time nor flow.*

[4] *Composite (Proportional) Samples (com-POZ-it). A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.*

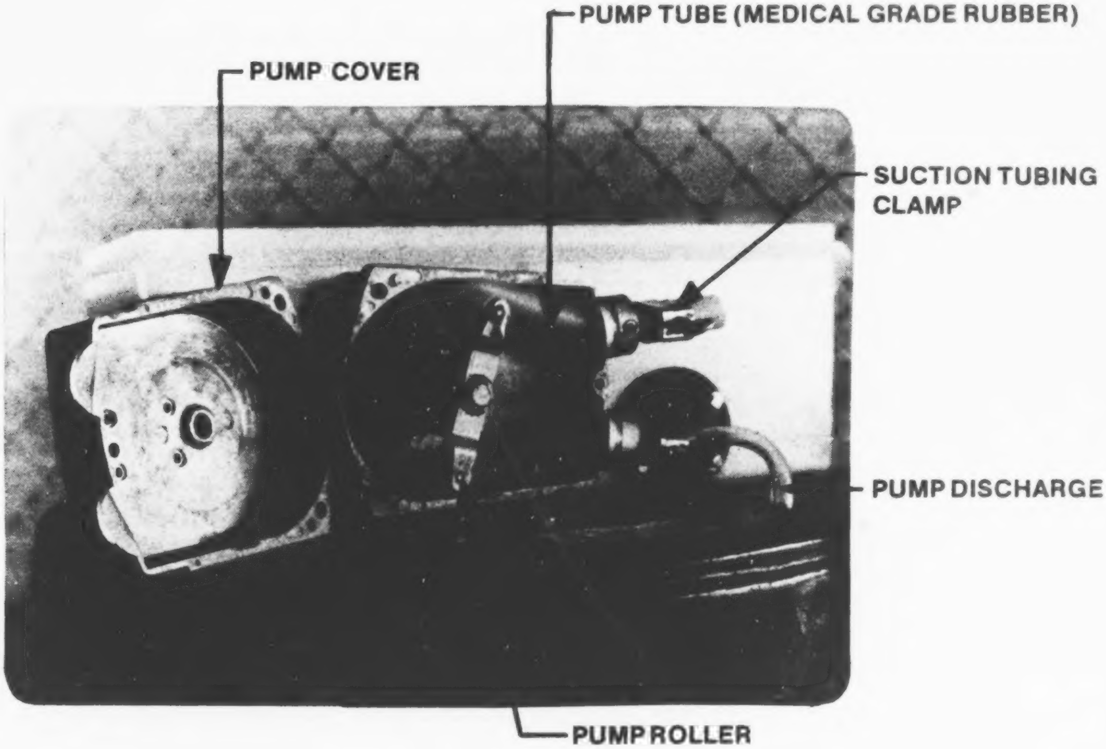
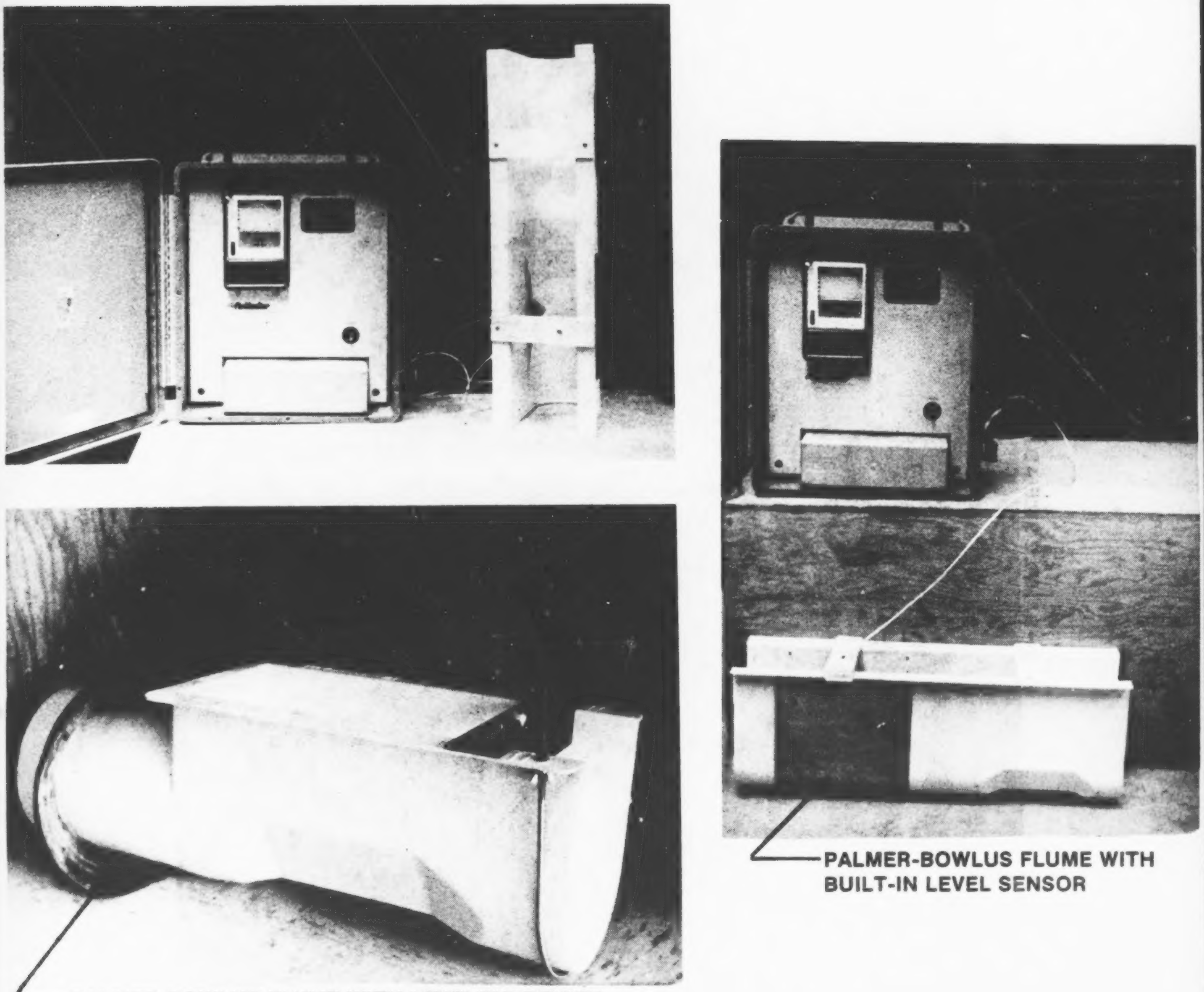

PUMP TUBE (MEDICAL GRADE RUBBER)
PUMP COVER
SUCTION TUBING CLAMP
PUMP DISCHARGE
PUMP ROLLER

Fig. 5.1 Peristaltic pump sampler



PALMER-BOWLUS FLUME WITH BUILT-IN LEVEL SENSOR

PALMER-BOWLUS FLUME WITH LEVELING DEVICE.

Fig. 5.2 Portable flow meters and recorders

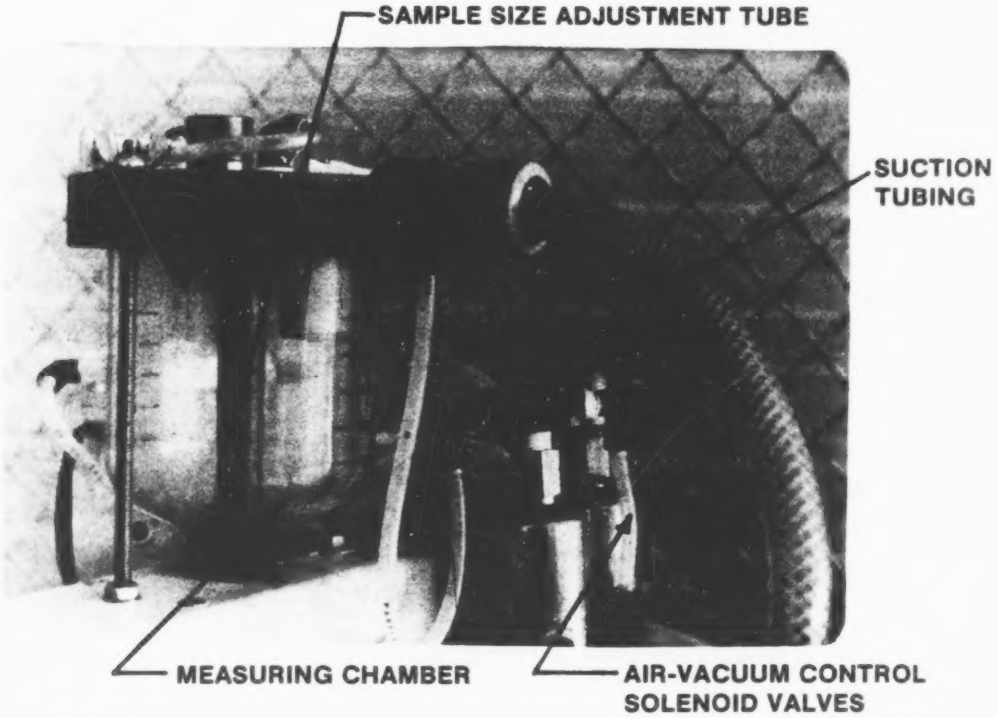

SAMPLE SIZE ADJUSTMENT TUBE
SUCTION TUBING
MEASURING CHAMBER
AIR-VACUUM CONTROL SOLENOID VALVES

Fig. 5.3 Vacuum chamber sampler

Most portable samplers use individual bottles for each sampling period. The bottles are on a rotating table or plate on a timer that positions a different bottle under the sampler discharge during each sampling time. This permits a sample from a particular sampling time to be individually inspected. The separate samples are combined to make a composite sample.

The usefulness of a portable sampler will depend on the flexibility of its controls. Desirable features include automatic purging before and after the sample is taken, and timing flexibility to allow a range of sample times from every few minutes to a couple of hours between samples. At times you may want to take more than one sample per bottle, or to fill several bottles during each sampling cycle. All of these features, plus other refinements, are provided by several manufacturers in their portable samplers.

Chilling the sample for preservation may be important (see Section 5.4 on sample preservation). An ice compartment is generally provided for this purpose. If the sampler is to be used in one location for some time, it may be practical to use chilled water. A small refrigerated-water chilling unit, a small water-circulating pump, and some plastic tubing will do the job. The tubing can enter the sampler by notching the cover, or short lengths of ⅛-inch (3 mm) pipe can be installed through the bottom by using lock nuts, washers, and a good sealant (Figure 5.4).

5.26 Handling Portable Samplers

Most portable samplers are designed to fit into a manhole and are equipped with harnesses to permit hanging them within the manhole. Usually missing is something to hook the harness to. Also missing is a way to keep the suction hose approximately in the middle of the wastewater flow. This is especially noticeable if you are sampling a *TRUNK SEWER*[5]. The following method has served well to overcome these problems. Many other ideas also will work with the individual situation and your ingenuity usually determining your approach.

Figure 5.5 shows a sampler and the gear for supporting it.

1. A special "manhole ring" (Figure 5.6) is suspended inside the manhole from the inside of the manhole frame. The manhole cover sits on top of the "manhole ring." The "manhole ring" can be made up by a sheet metal shop from 16-gage galvanized sheet metal. The ring cylinder should be slightly smaller than the inside diameter of the top of the manhole.
2. A harness for the sampler is made of nylon or other synthetic rope and attached to the "manhole ring" with harness snaps. Several harnesses of various lengths should be made for manholes of various depths. The harness snaps should be inspected frequently for possible replacement because they may corrode rapidly under conditions found in manholes.
3. A knotted rope is attached from the "manhole ring" to the sampler to raise and lower the sampler.
4. A piece of pipe with a bail on it is suspended from the sampler. This serves as a "hanging wet well." The suction line is taped to the bail to hold it in place, and a piece of nylon cord suspends it to the desired depth.

In a sewer, debris such as rags may hang up on this device, but it will swing downstream and the debris will slide off. In practice, this method has yielded good results with very few missed samples.

5.27 Care of Equipment

Cleanliness is a very important part of getting accurate tests. Contamination of sample containers, tubing, and internal parts of samplers will affect the sample, and thereby lead to inaccurate laboratory results.

Another potential problem that can lead to inaccurate test results is interference due to the type of material from which the tubing and containers are made. Depending on the materials, some elements in the wastewater may adsorb on the walls of the tubing or container. Also, some wastewater constituents may react with tube or container materials causing impurities that may dissolve into the sample. This is a greater problem with the containers because the contact time of the sample with the tubing is very limited. While this type of interference normally is not a problem, it is important when testing for very low levels of heavy metals and other toxins (i.e., in parts per billion or micrograms per liter). If you are faced with this situation, it is a good idea to obtain sample containers made from Teflon or linear polyethylene. These materials are excellent in that they don't adsorb materials from the sample or contain impurities that can dissolve into the sample.

5.28 Maintenance

The reliability of samplers varies considerably. A unit that is considered poor by one operator may perform well for another. The most reliable equipment will be that used where regular maintenance is performed in accordance with the manufacturer's instructions. Replacement items must also be as specified. For example, if a specific tubing is designated for a peristaltic pump, substitutes may cause malfunctions. Where samplers are equipped with desiccant (drying) cartridges, it is important to keep them changed as instructed. To service sampling equipment, both mechanical and electronic skills are required.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 260.

5.2E What are the differences between grab and composite samples from the standpoint of industrial waste monitoring? What are the problems with each type?

5.2F How is power provided for portable sampling equipment in the field?

5.2G Why is the flow velocity in the sampler suction tube important?

5.2H What kind of care and maintenance should be provided monitoring equipment?

END OF
LESSON 1
OF 2
LESSONS ON
INDUSTRIAL
WASTE
MONITORING

Work the discussion and review questions before continuing with Lesson 2.

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[5] *Trunk Sewer. A sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population.*

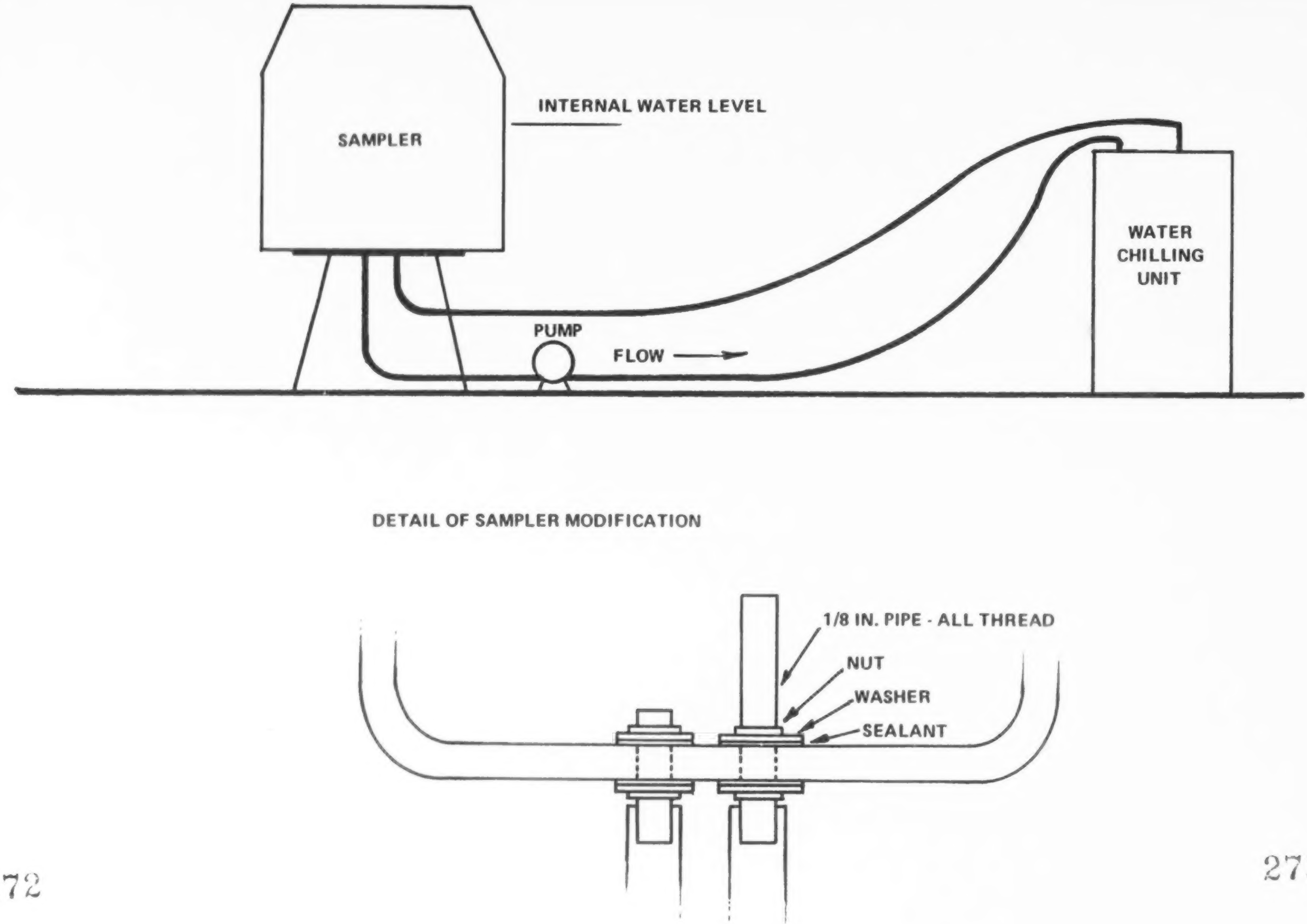
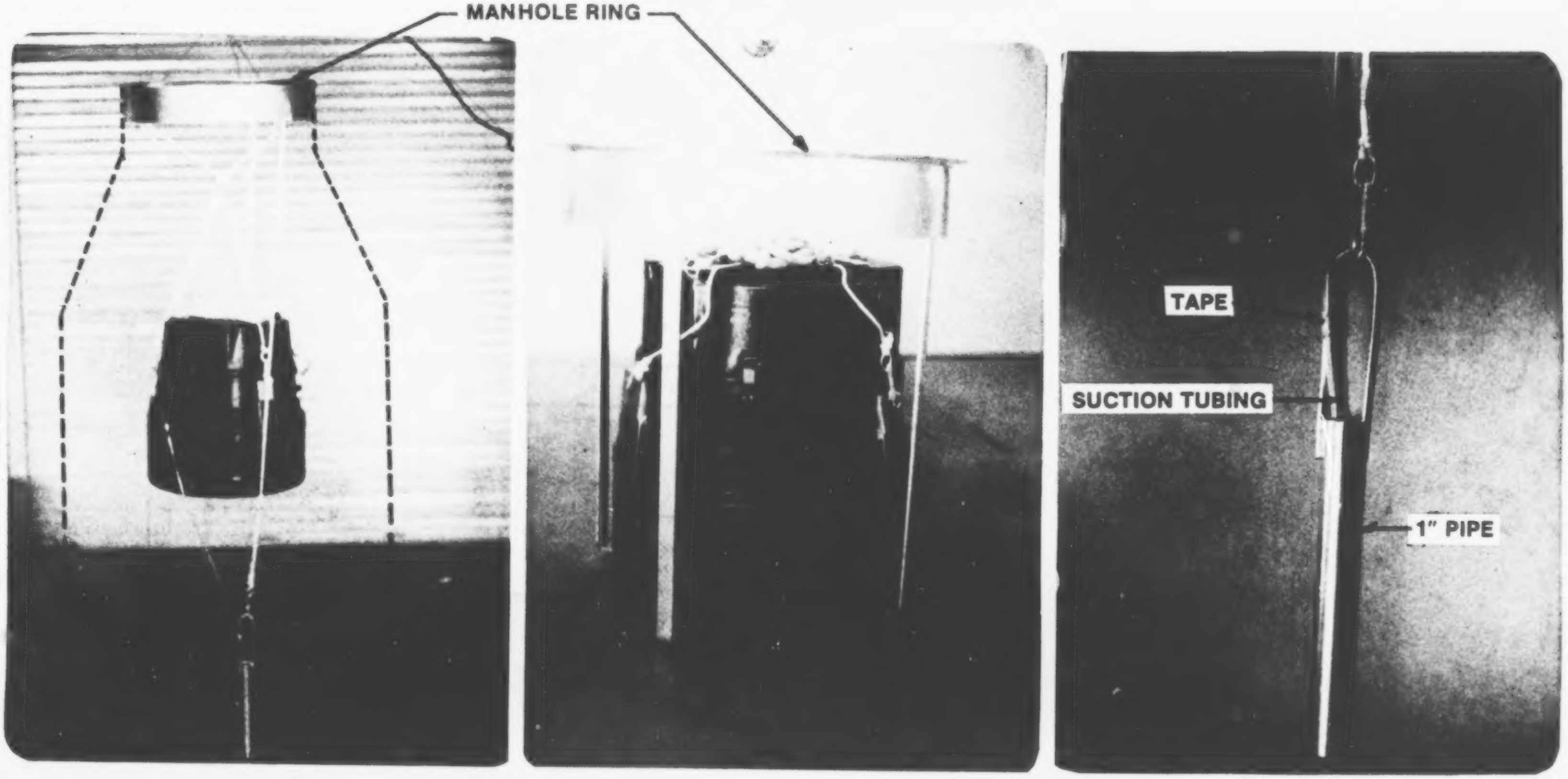

SAMPLER
INTERNAL WATER LEVEL
WATER CHILLING UNIT
PUMP
FLOW
DETAIL OF SAMPLER MODIFICATION
1/8 IN. PIPE - ALL THREAD
NUT
WASHER
SEALANT

Fig. 5.4 Sketch of arrangement for chilling sampled waters


MANHOLE RING
TAPE
SUCTION TUBING
1" PIPE

Sampler harness suspended from manhole ring. Note suction tube of sampler at bottom.

Entire sampler in rack may be raised or lowered by harness.

Protective tube around sampler suction tube.

Fig. 5.5 Hanging Sampler

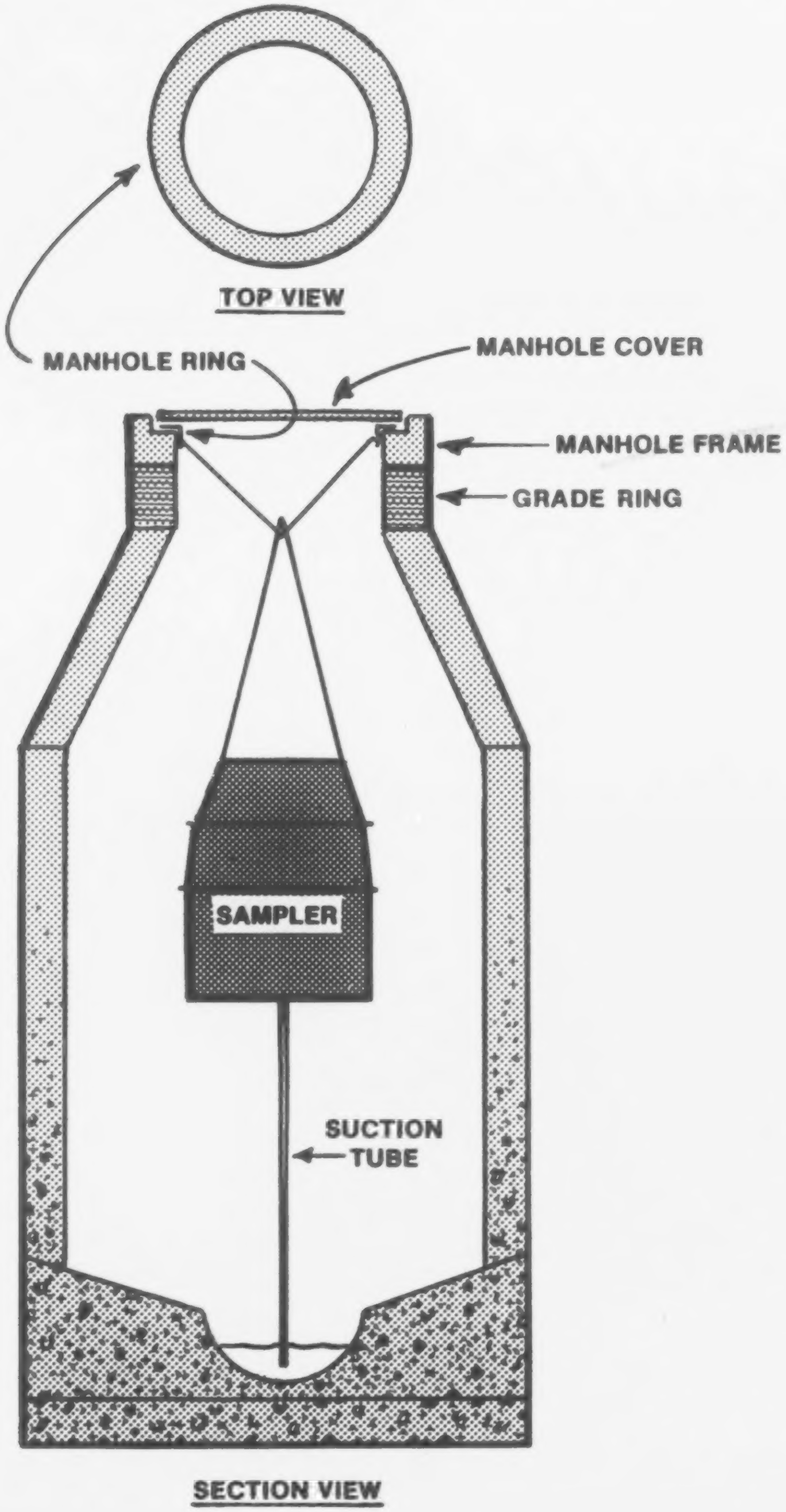

TOP VIEW
MANHOLE RING
MANHOLE COVER
MANHOLE FRAME
GRADE RING
SAMPLER
SUCTION TUBE
SECTION VIEW

Fig. 5.6 Special "manhole ring" details

DISCUSSION AND REVIEW QUESTIONS

CHAPTER 5. INDUSTRIAL WASTE MONITORING

(Lesson 1 of 2 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should answer before continuing. The purpose of these questions is to indicate to you how well you understand the material in this lesson. Write the answers to these questions in your notebook before continuing.

1. What adverse impacts can occur if an improperly pretreated industrial waste reaches a wastewater treatment plant?
2. How would you effectively deal with an industrial waste discharger?
3. Why must representative samples be collected?
4. How would you collect a representative sample when the wastewater has oil or other floating materials on the surface?
5. How would you attempt to determine the peak concentration and time of occurrence of a toxic waste discharge?

CHAPTER 5. INDUSTRIAL WASTE MONITORING

(Lesson 2 of 2 Lessons)

5.3 LOCATING SOURCES OF DISCHARGES

5.30 "Prospecting" in the Sewers

Often, the problem facing the wastewater treatment plant operator is that of an industrial waste from an unknown source. The magnitude of the problem is, of course, directly proportional to the problems caused by the unknown discharge. When trying to locate the source, established procedures must be followed to obtain accurate results. Some of the equipment used and techniques of locating the sources of discharges are discussed in Section 5.2, "How to Monitor Discharges."

To trace an industrial discharge causing problems, begin at the treatment plant or at a point in the collection system where the discharge has been discovered. If the discharge is visible through color or solids and continuous, simply inspect the sewer at each sewer line intersection and follow it up to its source. If a visual check isn't sufficient, use portable samplers in the same way. If several samplers are available, the process can be speeded up greatly.

If the discharge is intermittent, the task can be very difficult and time consuming. *SLUGS*[6] can pass by the sampler between sampling periods. If short sampling time intervals are used, the samplers must be inspected every few hours. Solvents float on the surface and will not be picked up by ordinary sampling equipment. If you are looking for petroleum solvents or similar floatable materials, you can fasten the suction tubing to a block of styrofoam or similar material and thus hold the suction end of the sampling tube very close to the surface.

Techniques other than sampling will be appropriate at times. For instance, a solvent discharge problem might be solved by inspecting all the shops, stores, service stations, and laundries connected to that part of the collection system. A survey of the area may prove to be helpful. Use the permit application forms provided in the Appendix (A and C) either directly, or use them as a guide for preparation of your own survey forms.

5.31 Identifying Waste Materials

Once a sample has been collected and analyzed by the laboratory, the next problem is to interpret the results. A list of the common types of discharges from some businesses or industries is contained in Table 5.1. Once the type of discharge is determined, one helpful source of information is the telephone directory. The "yellow page" listings can usually produce a list of firms or industries to inspect. Personal visits or inspections can then help to get the problem solved.

5.4 SAMPLE PRESERVATION AND SECURITY

5.40 Storage Time

Laboratory tests are most accurate if a sample is analyzed immediately after it is collected. Prompt testing prevents physical, chemical and/or biological changes in the sample. While immediate testing usually isn't possible, in most cases refrigeration adequately preserves the quality of the samples (see the sample preservation list in Table 5.2). A related problem arises when samples must be tested within a specified time after collection. For example, practically all BOD samples are from 24-hour composite samples plus additional storage time. As indicated on the list, the storage time for BOD is 48 hours. Even though you won't be able to get perfectly accurate test results under these circumstances, you can minimize the amount of error if you maintain a consistent storage time for each sample tested. This will maintain a constant degree of error on all samples, and thereby reduce errors in interpretation of results.

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[6] *Slugs. Intermittent releases or discharges of industrial wastes.*

TABLE 5.1 TYPES OF POLLUTANTS FROM SOME COMMON INDUSTRIES

	TYPES OF POLLUTANTS																	
Type of Industry	BOD	SUSPENDED SOLIDS	DISSOLVED SOLIDS	OIL AND GREASE	pH	TURBIDITY	COLOR	HEAT	HEAVY METALS	CYANIDE	AMMONIA	SULFATE	ALKALINITY	PHENOL	SULFITE	SETTLEABLE SOLIDS	SURFACTANTS	NUTRIENTS
Canneries	X	X			X											X		
Chemical Mfg.	X	X		X	X			X	X				X					
Dairy Products	X	X	X		X											X		X
Detergent Mfg.	X	X		X	X			X				X					X	
Electroplating		X	X		X		X		X	X								
Glass, Asbestos	X	X	X	X	X	X	X	X			X			X				
Grain Mills	X	X	X		X			X										X
Leather Tanning	X	X	X	X	X		X								X			
Meat Products	X		X	X												X		X
Rubber Products	X			X			X							X			X	
Sugar Processing	X	X	X		X			X										X
Paper Mills	X	X	X			X	X								X			X
Plastics	X	X			X				X					X				
Wood Products	X	X	X				X											

TABLE 5.2 RECOMMENDED STORAGE PROCEDURES AND SAMPLE PRESERVATION TECHNIQUES

RECOMMENDED STORAGE PROCEDURE

Analysis	**Sample Storage**	
	Refrigeration @ 4°C	**Frozen**
Total Solids	OK	OK
Suspended Solids	Up To Several Days	NO
Volatile Suspended Solids	Up To Several Days	NO
COD	Up To Several Days	OK
BOD	48 Hours For Grab Samples or Up To 48 Hours In Composite Sampling Systems	Lag Develops, Must Use Fresh Wastewater Seed

SAMPLE PRESERVATION

Analysis	**Preservative**	**Maximum Holding Period**
Acidity-Alkalinity	Refrigeration at 4°C	14 days
Biochemical Oxygen Demand	Refrigeration at 4°C	48 hours
Calcium	None required	7 days
Chemical Oxygen Demand	Add H_2SO_4 to pH <2 at 4°C	28 days
Chloride	None required	28 days
Color	Refrigeration at 4°C	48 hours
Cyanide	Add NaOH to pH >12 at 4°C	14 days
Dissolved Oxygen	Determine on site	No holding
Fluoride	None required	28 days
Hardness	HNO_3 to pH <2	6 months
Metals, Total	5 ml HNO_3 per liter	6 months
Metals, Dissolved	Filtrate: 3 ml 1:1 HNO_3 per liter	6 months
Nitrogen, Ammonia	H_2SO_4 to pH <2 at 4°C	28 days
Nitrogen, Kjedahl	H_2SO_4 to pH <2 at 4°C	28 days
Nitrogen, Nitrate-Nitrite	H_2SO_4 to pH <2 at 4°C	28 days
Oil and Grease	H_2SO_4 to pH <2 at 4°C	28 days
Organic Carbon	H_2SO_4 to pH <2 at 4°C	28 days
pH	Determine on-site	No holding
Phenolics	H_2SO_4 to pH <2 at 4°C	28 days
Phosphorous, Total	H_2SO_4 to pH <2 at 4°C	28 days
Solids	Refrigeration at 4°C	7 days
Specific Conductance	Refrigeration at 4°C	28 days
Sulfate	Refrigeration at 4°C	28 days
Sulfide	Zn acetate + NaOH to pH >9 at 4°C	28 days
Threshold Odor	Refrigeration at 4°C	7 days
Turbidity	Refrigeration at 4°C	48 hours

Sources: U.S. Environmental Protection Agency, *HANDBOOK FOR MONITORING INDUSTRIAL WASTEWATER* and U.S. Environmental Protection Agency, *FEDERAL REGISTER*, VOL. 49, NO. 209, Friday, October 26, 1984, Part VIII, *GUIDELINES ESTABLISHING TEST PROCEDURES FOR THE ANALYSIS OF POLLUTANTS UNDER THE CLEAN WATER ACT; FINAL RULE AND INTERIM FINAL RULE AND PROPOSED RULE*, pages 28 and 29.

5.41 Storage Temperature

The recommended temperature for sample storage is 4°C. At this temperature, the rate of chemical reactions and biological activity is significantly reduced. Set the control on the refrigeration unit in permanent installations or chilling water unit for a modified portable sampler. When using portable samplers in the field, put ice on the compartment and hope for the best. If you are working where the wastewater stream is warm, you can use dry ice. Experiment to find out how much to use (too much may freeze the samples). Samples must be kept chilled while they are being transported to the laboratory.

5.42 Chemical Preservation

In some cases, it is appropriate to add chemicals to preserve the samples (See Table 27.2 for detailed recommendations.) For portable samplers, the chemical can be measured into each sample bottle in advance.

5.43 Security

Once a sample has been obtained and is ready for laboratory analysis, it is extremely important to insure that each sample is carefully labeled. Test results are useless if there is any doubt that they are for the correct sample. A good starting point is to firmly affix a label or tag to the sample container (Figure 5.7). Another reason for careful labeling is so the "chain of possession" is traceable. If legal action results, you must be able to prove that the sample was in the possession of responsible people at all times and also that no one tampered with the sample.

A logging or "sign-in" system should be used at the laboratory. This system should include the name of the person delivering the sample as well as the date and time received. The laboratory should then assign a number which identifies the sample and appears on the laboratory report.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 260.

5.3A How would you attempt to trace or locate an industrial waste discharge?

5.3B How can the intake for an automatic sampler be adjusted to sample solvents or other floatables?

5.4A Why should a sample be analyzed as soon as possible?

5.4B Why are samples stored at 4°C?

5.5 FLOW METERING

5.50 Need for Accurate Measurements

Measuring the flow from an industry is equally as important as obtaining good samples. The quantity of pollutants cannot be calculated without accurate flow data. Knowledge of the quantities of pollutants from the various industries is essential to reaching decisions regarding pretreatment requirements to be set, and also to prepare accurate and equitable billing calculations. Flow and pollutant data on industries also may be an important part of the design work for future expansions or new facilities. Flows indicate the hydraulic loading on both the collection system and the wastewater treatment facilities.

5.51 Water Meters

In many cases, the flow to the sewer can be calculated based on data from water meters placed on public water supplies or private wells. When water-meter data is used, allowances may have to be made for evaporation, irrigation, or water used in the product (e.g., soft drinks). Water meters on boiler feed lines, product lines, or irrigation water will serve to verify this type of usage.

For the larger industries, open-channel flow meters such as Parshall flumes generally are used. For these ("fixed") installations, the same type of equipment is used as for treatment plants. Refer to the section on metering in Chapter 15, "Maintenance," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS*, for detailed information.

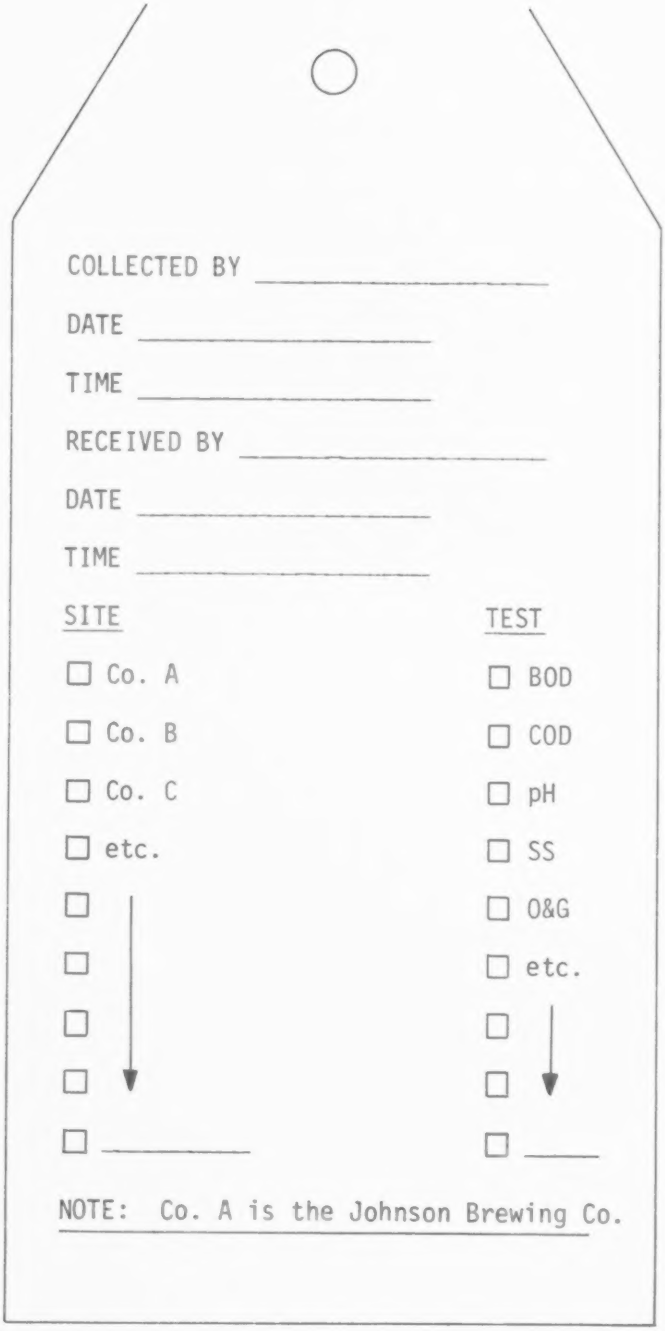
For the smaller enterprises, portable metering equipment often is installed in existing collection systems. There are many types of portable meters available. The standard approach is to use a compact flume, such as a Palmer-Bowlus flume, as the primary flow-measuring device. Some compact flumes have provisions for several types of primary devices (flumes, V-notch and rectangular weirs) for measuring the flows. The level in the primary device is sensed by a float, bubbler, electrical probe, sonar (ultrasonic), or built-in capacitance sensor in the flume. The meters generally are equipped with a totalizer and small strip-chart recorder, although at least one manufacturer uses a circular chart. Also, there is usually a connection for controlling a sampler so that flow-proportional sampling can be done in the field.

If you are purchasing a flow meter and the recorder is an optional feature, you are strongly advised to include the recorder. Knowing the flow pattern can be very helpful in evaluating the discharges by an industry, and perhaps in helping them to correct problems.

5.6 SAFETY

5.60 Traffic Safety

Obtaining a sample from a manhole in the street without getting run over requires some advance preparation and effort. Table 5.3 shows a good example of a traffic safety instruction sheet. Follow these instructions very carefully as they apply to your situation every time you must collect a sample from a manhole in a street. Figure 5.8 shows how cones may be used in a typical layout for blocking one lane of the street when you must work in the street. Proper and improper barricades for directing traffic are shown in Figure 5.9.



COLLECTED BY ____________________

DATE ____________________

TIME ____________________

RECEIVED BY ____________________

DATE ____________________

TIME ____________________

SITE

☐ Co. A
☐ Co. B
☐ Co. C
☐ etc.
☐
☐
☐
☐
☐ __________

TEST

☐ BOD
☐ COD
☐ pH
☐ SS
☐ O&G
☐ etc.
☐
☐
☐ _____

NOTE: Co. A is the Johnson Brewing Co.

Fig. 5.7 Label or identification tag for sample container

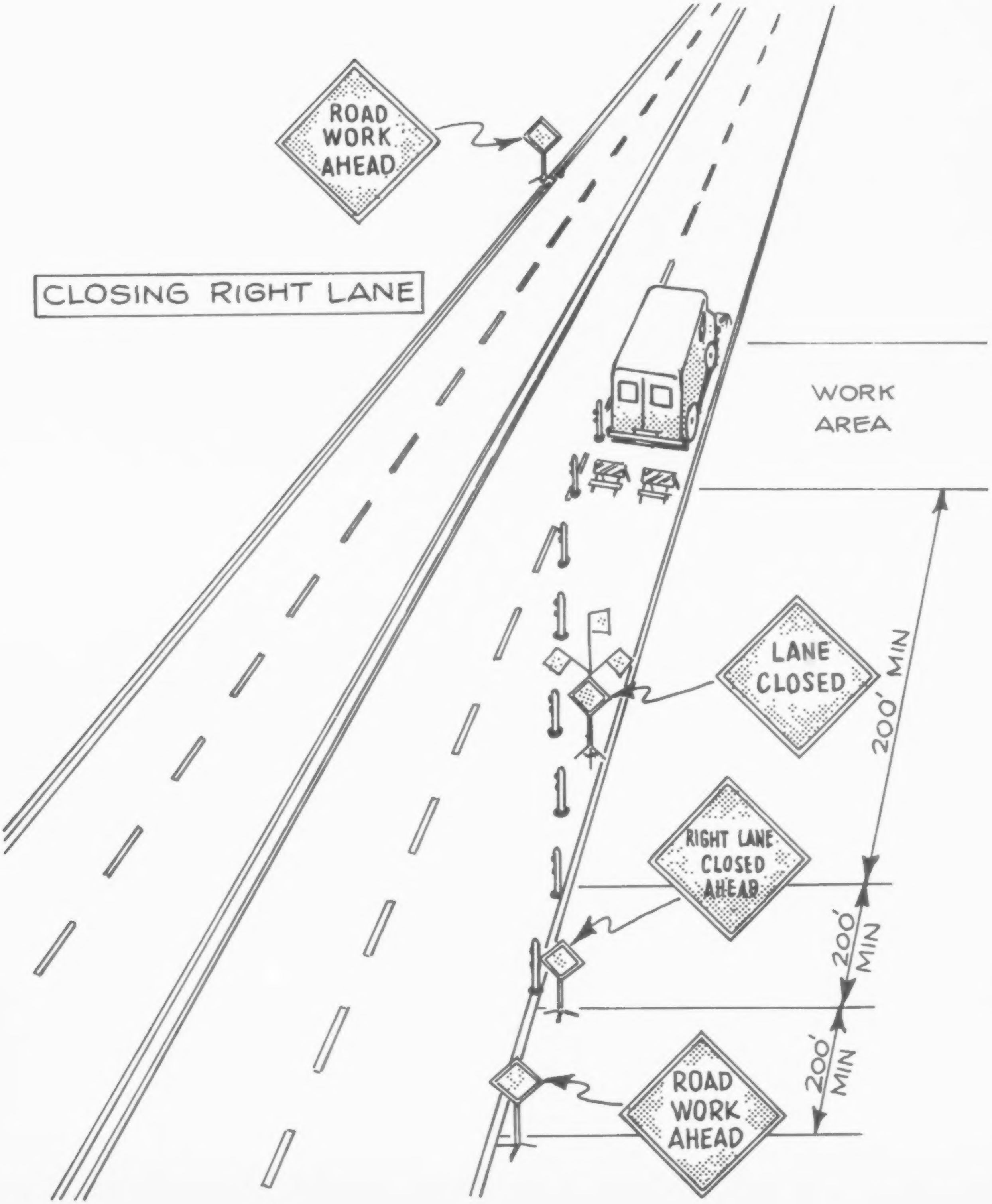

ROAD WORK AHEAD
CLOSING RIGHT LANE
WORK AREA
LANE CLOSED
200' MIN
RIGHT LANE CLOSED AHEAD
200' MIN
200' MIN
ROAD WORK AHEAD

Fig. 5.8 Typical layout for blocking one lane of traffic

(Source: Work Area Traffic Control by San Diego County Chapter, American Public Works Association.)

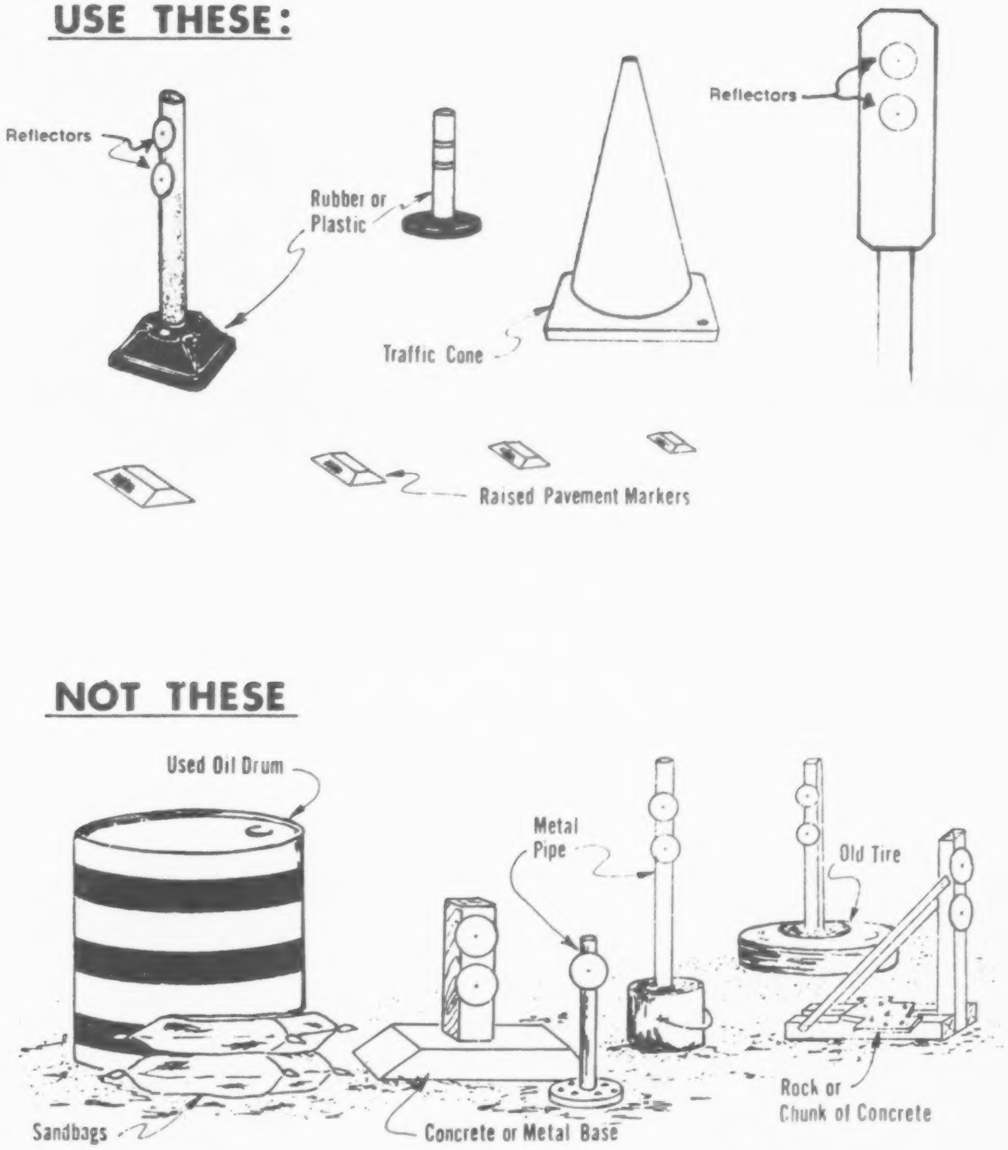

USE THESE:
Reflectors
Rubber or Plastic
Traffic Cone
Reflectors
Raised Pavement Markers
NOT THESE
Used Oil Drum
Metal Pipe
Old Tire
Sandbags
Concrete or Metal Base
Rock or Chunk of Concrete

Fig. 5.9 Proper and improper barricades for directing traffic

(Source: Work Area Traffic Control by San Diego County Chapter, American Public Works Association.)

TABLE 5.3 TRAFFIC SAFETY INSTRUCTIONS

Safe working conditions must be maintained at all times. This is especially important when taking samples from manholes located within normal traffic lanes.

The important considerations are: (1) to be visible to oncoming traffic, and (2) to guide this traffic safely around you. The following basic procedure is for your general guidance. (For unusual situations, look at the situation carefully and use common sense. If you consider a particular location too hazardous, skip that location and contact your supervisor for advice.)

1. Wear red safety vest, hard hat, and safety glasses.
2. Slow down in advance of work area. Use hand signals and turn on beacon (the rotating yellow light on the vehicle roof). Do not stop suddenly.
3. Park vehicle between you and the prevailing traffic, about 10 feet (3 m) away from work area.
4. Turn wheels away from you and oncoming traffic, set hand brake firmly, and place in parking gear.
5. Leave vehicle carefully — set out traffic cones as quickly and as safetly as possible. Figure 27.8 shows how cones may be used for blocking one lane of a street. Proper and improper barricades for directing traffic are shown in Figure 27.9.
6. Be alert to the traffic at all time.
7. Finish all work and be ready to go before retrieving traffic cones.

5.61 Confined Spaces

Use a manhole hook or manhole lift to open manhole covers. Do *NOT* use a bar because if you jab with it, you may cause a spark which could be disastrous if an explosive atmosphere existed in the manhole. When a manhole cover is off, guard the area around the open manhole with traffic cones or a portable guardrail. Remove items from shirt pockets before working over the open manhole. When replacing the cover remove any dirt or other debris from the base, so that the cover will seat properly.

OSHA[7] regulations (and common sense) dictate several precautionary measures which must be taken before entering manholes or other areas that may be confined spaces. Before entering an area that may be a confined space, the atmosphere in the area must be tested for oxygen deficiency, toxic gases (e.g., hydrogen sulfide), and explosive conditions (Lower Explosive Limit). If you discover explosive conditions, you must not enter. NOTIFY THE PROPER AUTHORITIES IMMEDIATELY. If there is an oxygen deficiency, you may use a self-contained breathing apparatus only for emergency entry. Correct any situation in which an oxygen deficiency exists or toxic gases are encountered by providing adequate ventilation. Do not work in a confined space until all detection devices indicate that the area is safe for entry. The important fact to remember is that you seldom get a second chance. *BE SURE* it's safe before entering confined spaces.

If there is no oxygen deficiency, no toxic gases and no explosive conditions, the area or space is considered *NOT CONFINED*. Before entering the area, you must be wearing a safety harness. Two people must be standing by topside to help the person out of the hole or area in an emergency. The atmosphere in the area must be continuously monitored (oxygen, toxic gases, explosive conditions) whenever anyone is working in the hole. If the monitor alarm goes off, the person in the hole must be removed immediately.

NEVER enter a confined space even with a self-contained breathing apparatus and sufficient people standing by unless you absolutely must enter the space. If at all possible eliminate the hazardous condition creating the confined space before entering and working in the area.

For details on safe traffic regulation and manhole entry, see Chapter 4, "Safe Procedures," in *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS* by John Brady and Kenneth D. Kerri.

5.62 Equipment Storage

Orderliness is the key to avoiding accidents and equipment damage in the storage area. Common hazards include items protruding from shelves, items falling from shelves, and items placed in normal traffic patterns on the floor. Containers should be cleaned before storage and protected so they will stay clean. Chemicals should be stored separately from other items, with a separate room being preferable. All reagent bottles must be marked with the date opened or the date the reagents were prepared.

5.63 Battery Charging

There are some hazards to consider when using samplers which operate from lead-acid batteries. When a lead-acid battery is being charged, hydrogen is given off. Therefore, good ventilation is essential. New batteries must be shipped dry; therefore, you must add the electrolyte (diluted sulfuric acid) yourself. Protective clothing (goggles, gloves, aprons) must be worn. Eyewash facilities must be provided. Some excerpts from safety orders for battery charging are given in Appendix D.

5.7 MONITORING STRATEGIES

5.70 Development of Strategies

The following discussion is based on the assumption that an industrial discharge is the cause of the particular problem under consideration. This will, of course, be obvious in many cases. However, the "state of the art," particularly regarding activated sludge, is not sufficiently advanced that the operator can always be certain about the effects of a particular industrial discharge. A process that is not completely healthy may be seriously upset by a discharge that would otherwise have little effect. Extremely small quantities of certain exotic chemical compounds (such as pesticides) may upset the process, and not be detected at all by most monitoring programs. These items are very important when preparing a plan of action on how to operate wastewater treatment plants that must handle industrial wastes.

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[7] *OSHA. The Williams-Steiger Occupational Safety and Health Act of 1970.*

5.71 Regulation of High Flows

Hydraulic loading is an important factor in plant performance. The flow from an industry may greatly affect a treatment plant, particularly where a sizeable industry has located in a smaller community. Regulation of the industrial flow to coincide with low domestic flow periods may be required. Seasonal industries, such as canneries, or vacation shutdown periods may have a significant impact on treatment plant operation.

5.72 Decisions on Industrial Discharges

When a new industry is locating in your area, decisions will have to be made regarding pretreatment, controlled timing or rate of discharge and installation of monitoring equipment. Several basic items need to be covered. Will there be any toxic or hazardous materials in the discharge? Will there be discharges that can cause problems in the sewers (e.g., oxygen consuming wastes, explosive hazards, or solids settling)? Calculate what the BOD loading will be and compare it to the design capacity (less present loading) of the treatment plant. Consider whether there might be clarifier hydraulic overloading or excessive floatable or settleable solids. High solids loading could lead to overloading the solids treatment capacity of the digesters.

If a color is to be discharged, will it be from dyes or food colors? Food coloring usually is no problem, because the colors disappear within the plant processes. Other sources of color will require some testing. Some wastes can be treated by acclimatizing organisms to the specific toxic materials present in the wastes. This is usually best handled by a pretreatment process at the industry.

In general, you would not want to allow one new firm or industry to use up all of the remaining hydraulic, BOD, or solids capacity in your treatment plant. A new industry often will attract more businesses, provide more jobs and cause an increase in home construction. Some plant capacity should be reserved for these other or secondary activities resulting from a new industry.

Tables 5.1 (page 248), 5.4 and 5.5 summarize helpful information indicating what to expect when evaluating the potential impact of a new industry. These tables indicate the types of wastes than can be expected, whether they might interfere with the treatment processes and whether the pollutants might pass through a treatment plant untreated.

5.73 Reaction to Industrial Discharges

Table 5.6 lists some common industrial discharge situations and possible problems that may result, and suggested actions to take. The table is useful primarily as an "idea file." A listing of all the types of discharges that might occur is impossible as is providing a specific corrective action for each possible case or problem. The operator should review the situations listed plus any others that might be peculiar to the community, and prepare for these possibilities. Preplanning will allow you to implement preventive maintenance measures such as the purchase of neutralizing chemicals or construction of a holding basin.

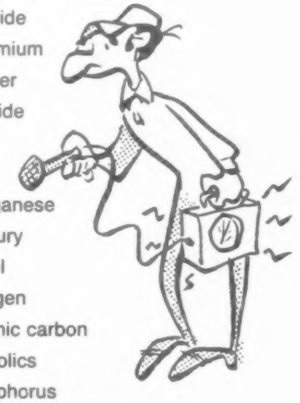
TABLE 5.4 POLLUTANTS THAT MIGHT INTERFERE WITH WASTEWATER TREATMENT PLANTS

Inorganic Substances	Organic Substances	Other Substances
Acidity, alkalinity and pH	Alcohols	Corrosive materials
Ammonia	Agricultural chemicals	Explosives and flammable materials
Alkali and alkaline earth metals	Carbon tetrachloride	High temperature wastes
Arsenic	Chlorinated hydrocarbon	Materials that cause blockages
Borate (and other boron species)	Chloroform	
Bromine	Methylene chloride	
Cadmium	Miscellaneous organic chemicals	
Chloride	Oils and grease	
Chlorine	Organic nitrogen compounds	
Chromium	Phenols	
Copper	Surfactants	
Cyanide		
Iron		
Lead		
Manganese		
Mercury		
Nickel		
Silver		
Sulfate		
Sulfide		
Zinc		

Source: *JOINT TREATMENT OF INDUSTRIAL AND MUNICIPAL WASTEWATERS*, Water Pollution Control Federation, Washington, D.C.

TABLE 5.5 POLLUTANTS THAT MIGHT PASS THROUGH WASTEWATER TREATMENT PLANTS

Cadmium
Chloride
Chromium
Copper
Cyanide
Iron
Lead
Manganese
Mercury
Nickel
Nitrogen
Organic carbon
Phenolics
Phosphorus
Radioactive wastes
Suspended solids
Zinc



Source: *JOINT TREATMENT OF INDUSTRIAL AND MUNICIPAL WASTEWATERS*, Water Pollution Control Federation, Washington, D.C.

TABLE 5.6 REACTIONS TO INDUSTRIAL DISCHARGES

SITUATION	PROBLEM	ACTIONS
1. Gasoline, solvent; other hydrocarbons	a. Explosive or flammable conditions in wet wells and headworks	a. Hold gasoline or solvent on top of primary clarifiers and allow wind to disperse fumes. b. Inspect wet well headworks ventilation and provide extra ventilation with blowers only (no suction of vapors into fans). c. Divert to holding basin. d. Keep personnel clear of area. e. Pure oxygen plants. Vent and purge reactors with air. Shut down oxygen feed until L.E.L. out of alarm range and normal readings are obtained.
	b. Possible damage to secondary processes	a. Watch DO levels, waste and return sludge rates.
2. Excessive solids	a. Cause stoppages in sewers	a. Flush sewers.
	b. Overload treatment processes	a. Increase pumping from clarifiers. b. Balance feed to digesters. c. Watch for septic conditions in primary clarifiers. d. Watch for low DO in aeration systems.
3. Acid or caustic wastes	a. Toxic to organisms in biomass	a. Neutralize. b. If too late and the biomass is damaged, adjust air rates, wasting rates, and foam control devices. Increase chlorine dosage for adequate disinfection.
4. Color and turbidity	a. Color and turbidity in effluent	a. Food colors assimilated in secondary processes. b. Trace discharge back to source. c. Wastes from different industries may combine to form permanent colors. Control colors at source.
5. High temperature waste	a. Septic conditions in sewers	a. Try prechlorination to correct.
	b. Upset biological treatment processes	a. Stop high temperature discharges at source.
	c. Trickling filter ponding	a. Increase recirculation rates.
	d. Increased oxygen demand	a. More air is required in activated sludge process.
6. High organic load (suspended and dissolved solids)	a. Septic conditions in sewers	a. Try prechlorination to correct.
	b. Upset biological treatment processes	a. Activated sludge. (1) More air required. (2) Fast solids build-up. Try increasing wasting. (3) Foam. Try using sprays and/or defoamers. b. Trickling filters. Increase recirculation rates.
7. Oil and grease	a. Grease build-up in sewers	a. Clean more frequently.
	b. Scum blankets in digesters	a. Increase mixing.
	c. Excessive grease in clarifier scum box. Difficulty in pumping.	a. Try removing grease more frequently.
	d. Secondary processes (1) May carry oil and grease over weirs (2) Trickling filters. Plugged orifices and ponding. (3) Activated sludge. Oil coats biomass and foam problems develop.	a. Increase maintenance. (1) Increase skimming at clarifier surface. (2) Increase frequency of cleaning and hosing. (3) Skim floating sludge and scum from surface of secondary clarifiers.

TABLE 5.6 REACTIONS TO INDUSTRIAL DISCHARGES (Continued)

SITUATION	PROBLEM	ACTIONS
8. Toxic substances (heavy metals and pesticides)	a. Usually not detected in plant effluent b. Plant processes deteriorate c. Trickling filter sloughing can occur d. Extensive lab work to identify material	a. Prevent from entering collection system. b. Try to build up biomass by stopping all sludge wasting and return sludge rates. If necessary, obtain seed sludge from another plant. c. If wasting is continued, do not waste toxic substances to another biological process (aerobic or anaerobic digester). Try to minimize wasting of helpful organisms. d. Usually less air is required because of reduced biological activity. Excess air rates may strip out some toxic substances. e. Increase foam control if necessary. f. Find out what is being discharged and trace to source.
9. Nutrients (nitrogen and phosphorus)	a. Poor removals of nutrients by conventional plant processes and may cause aquatic growths in receiving waters.	a. Source control of nutrients. b. Tertiary treatment to remove nutrients.
	b. Conversion of ammonia nitrogen to nitrite nitrogen will cause high chlorine demands and possibly reduce coliform kills.	a. Change process to avoid converting ammonia to nitrite by lowering DO levels and MCRT.
10. Taste and odor problems	a. Undesirable tastes and odors in drinking waters	a. Phenolic compounds good example. They pass through the plant and cause water supply problems. Control at source. b. Carefully control chlorine so tastes and odors won't get worse.
	b. Hydrogen sulfide from: (1) Septic conditions in sewers (2) Tannery and other wastes	a. Control hydrogen sulfide. (1) Try prechlorination. (2) Control at source.
11. Pathogenic wastes Radioactive wastes	a. Harmful to humans and usually not detectable at treatment plant	a. Control at source, such as hospitals and clinics.
12. Hydaulic shock load	a. Overload treatment processes	a. Reduce if possible by: (1) Diverting to storage basin; and/or (2) Restricting influent flow. b. Increase chlorination rate.
	b. Activated sludge process may lose solids	a. Stop wasting.

5.74 Warning Systems

Continuous monitoring and alarm systems for treatment plant influents are becoming common. Conductivity, pH, explosive atmosphere (L.E.L.), and oxygen deficiency detectors are suitable for continuous monitoring. Special sensors are available for many wastewater constituents; however, few are suitable at present for continuous use. High water level or flow alarms are available to warn of surges or hydraulic overloads.

The operator should keep abreast of progress in this field. Reading the technical journals and attending seminars and conferences will help to keep you current.

5.8 ADDITIONAL READING

1. *MOP 11,* Chapter 29,* "Effects of Industrial Wastes on Wastewater Treatment."
2. *NEW YORK MANUAL,* Chapter 10, "Industrial Wastes."
3. *TEXAS MANUAL,* Chapter 26, "Industrial Wastes."
4. *HANDBOOK FOR MONITORING INDUSTRIAL WASTEWATER,* U.S. Environmental Protection Agency, Technology Transfer, Cincinnati, Ohio 45268.
5. *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS,* Volumes I and II. Kenneth D. Kerri and John Brady, California State University, Sacramento, 6000 Jay Street, Sacramento, California 95819. Price $25.00 per volume.
6. *PRETREATMENT FACILITY INSPECTION,* Kenneth D. Kerri, California State University, Sacramento, 6000 Jay Street, Sacramento, California 95819. Price $25.00.
7. *STANDARD INDUSTRIAL CLASSIFICATION MANUAL 1987,* Stock Number 041-001-00314-2, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $24.00.
8. *INDUSTRIAL WASTEWATER CONTROL PROGRAM FOR MUNICIPAL AGENCIES,* MOP OM-4, Publications Order Department, Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314. Order No. MOM40H0. Price $13.50 to members; $18.00 to others.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 260.

5.5A Why should the flow from an industry be measured?

5.6A List the major areas of potential safety hazards while monitoring industrial wastes.

5.7A How would you regulate or handle a large, fluctuating industrial flow that hydraulically overloads a treatment plant during the day?

5.7B What types of potentially harmful industrial waste discharges can be continuously monitored and connected to alarm systems?

END OF LESSON 2
OF 2 LESSONS ON
INDUSTRIAL WASTE
MONITORING

Work the next portion of the discussion and review questions before continuing with the objective test.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 2 Lessons)

Chapter 5. INDUSTRIAL WASTE MONITORING

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 1.

6. How would you attempt to locate an industrial waste discharge that is causing problems?
7. Why is the "chain of possession" of a sample important?
8. How would you measure the flow from an industry?
9. How could you check or verify the accuracy of an industrial laboratory analyzing samples from its own self-monitoring program?
10. What are the potential hazards that could be encountered when entering a manhole?
11. What basic items would you consider when reviewing the application or permit of an industrial waste discharger?
12. What would you do if a gasoline or solvent was discovered on the surface of the wet well in the headworks of your treatment plant?

PLEASE WORK THE OBJECTIVE TEST NEXT.

SUGGESTED ANSWERS

Chapter 5. INDUSTRIAL WASTE MONITORING

Answers to questions on page 237.

5.0A Objectives of an industrial waste monitoring program include:

1. Prevention of shock loads on treatment processes;
2. Provision of physical protection for personnel and facilities;
3. Prevention of discharge of pollutants from treatment plants; and
4. Provision of a data base for equitable sewer-use charges and for engineering design.

5.0B Adverse characteristics of industrial wastes that could have serious impacts are:

1. Collection systems — acid wastes, thermal wastes, solids, oil and grease, odors, toxic substances, flammable and explosive material; and
2. Treatment plants — organic overload, toxic substances, oil and grease, acids and alkalies, hydraulic overload, materials not removed by plant processes and other hazardous wastes.

Answers to questions on page 238.

5.1A A good data base on industrial waste discharges is important in making decisions regarding treatment of plant process control, billing or use charges, documentation of incidents, and engineering design work.

5.1B Information collected to develop a data base includes industry identification, flow data, laboratory results, billing information, treatment information, reports of unusual circumstances or incidents, industrial facilities and emergency information.

5.1C A sewer-use ordinance should provide authority for the following enforcement activities:

1. Inspecting and monitoring,
2. Requiring pretreatment and/or flow adjustment,
3. Curtailing or ceasing of discharge,
4. Requiring spill protection measures,
5. Issuing permits to dischargers, and
6. Collecting money by billing for treatment provided.

Answers to questions on page 239.

5.2A Self-monitoring programs are commonly used in large industrial areas because the burden of monitoring a large number of industries would be overwhelming to a local agency.

5.2B Sensors used in continuous monitoring programs may require frequent cleaning and calibration to maintain their accuracy.

5.2C Representative sample. A portion of material or water identical in content to that of the larger body of material or water being sampled.

5.2D Attempt to collect representative samples at sampling points where the wastewater flow is well mixed.

Answers to questions on page 243.

5.2E The differences between grab and composite samples include:

1. Grab samples are simpler and less expensive. While they can indicate the contents of the waste stream at the time of sampling, they are not useful for variable discharges.
2. Composite samples provide a more accurate representation of a wastewater stream. A problem with composite samples is that peak concentrations of toxic substances may be missed.

5.2F Portable sampling equipment obtains power in the field from rechargable batteries or, when possible, from a 110-volt AC line using a "power pack."

5.2G The flow velocity in the sampler suction tube is important in obtaining repeatable results. If velocities are too low, solids will be left behind in the tubing. If velocities are too high, large chunks of material may be pulled into the sample and yield erratic results.

5.2H Monitoring equipment should be kept clean at all times to avoid contaminating samples. Regular maintenance should be performed in accordance with the manufacturer's instructions.

END OF ANSWERS TO QUESTIONS IN LESSON 1.

Answers to questions on page 250.

5.3A An industrial waste discharge may be traced or located by looking for signs or evidence of the waste. Begin at the treatment plant or collection point where the waste has been discovered, then follow signs of the waste back to the source. Look for indicative color or solids. If the discharge is not visible, use portable samplers to follow the waste to its source.

5.3B The intake to an automatic sampler can be adjusted to sample solvents or other floatables by fastening the suction tubing to a block of styrofoam or other similar material to hold the suction very close to the surface.

5.4A A sample should be analyzed as soon as possible to prevent physical, chemical or biological changes in the sample.

5.4B Samples are stored at 4°C to reduce the rate of chemical reactions and biological activity.

Answers to questions on page 258.

5.5A The flow from an industry should be measured to determine the hydraulic loading on the collection system and the treatment facilities and also to determine the quantities of pollutants or wastes discharged.

5.6A Major areas of potential safety hazards while monitoring industrial wastes include:

1. Traffic safety.
2. Confined spaces.
3. Equipment storage areas.
4. Battery charging.

5.7A If an industry hydraulically overloads a treatment plant during the day, try requiring the industry to store a portion of its discharges during peak flow periods for release during low flow periods such as the graveyard shift.

5.7B Potentially harmful industrial waste discharges that can be continuously monitored and connected to alarm systems include conductivity, pH, explosive atmosphere, and oxygen deficiency conditions.

END OF ANSWERS TO QUESTIONS IN LESSON 2

OBJECTIVE TEST

Chapter 5. INDUSTRIAL WASTE MONITORING

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

1. Industrial wastes can have undesirable impacts on both collection systems and treatment plants.
   1. True
   2. False
2. When dealing with an industrial waste discharger, be sure that you can show the need for any necessary action.
   1. True
   2. False
3. A good sampling point is easily accessible and located anywhere that a representative sample can be obtained.
   1. True
   2. False
4. Composite samples always reveal peak concentrations of toxic waste discharges.
   1. True
   2. False
5. A block of styrofoam or other similar material can be used to hold the suction end of a sampling tube very close to the surface when sampling for petroleum solvents or similar floatable materials.
   1. True
   2. False
6. Chemicals may be added to preserve samples in some cases.
   1. True
   2. False
7. Cleanliness is not important to sampling accuracy.
   1. True
   2. False
8. A knowledge of traffic safety is very important for persons involved in industrial waste monitoring.
   1. True
   2. False
9. Extremely small quantities of certain exotic chemical compounds (such as pesticides) may upset the activated sludge process, and not be detected at all by most monitoring programs.
   1. True
   2. False
10. If a new industry wants to use all of the remaining hydraulic and BOD capacity in your treatment plant, this request should be granted.
    1. True
    2. False
11. Why should industrial wastes discharged into a collection system be monitored?
    1. To impose fines on industries
    2. To prevent shock loads from upsetting wastewater treatment processes
    3. To protect operators of wastewater collection systems and treatment plants from hazardous and toxic substances
    4. To protect the public by preventing toxic industrial wastes from reaching drinking water supplies
    5. To protect wastewater collection and treatment facilities from corrosive and other harmful substances
12. Information on file for each industrial waste discharger should include
    1. Calculations used to determine billings.
    2. Flow data and lab analyses of discharges.
    3. Names and phone numbers of at least two representatives of the industry with authority to act in an emergency.
    4. Profits earned by industry last year.
    5. Total number of employees.
13. SIC stands for
    1. **S**elected **I**ncidents of **C**atastrophes caused by industrial wastes dischargers.
    2. **S**elected **I**ndustrial **C**ases of solutions to industrial problems.
    3. **S**i**c**knesses caused by industrial wastes.
    4. **S**tandard **I**ndustrial **C**lassification of industries.
    5. **S**tandard **I**ndustrial **C**ode of industrial wastes.
14. Before visiting an industry with an industrial monitoring program, the file should be reviewed. The file should contain a layout of the industry showing location of
    1. Chemical storage areas.
    2. Person to contact upon arrival for inspection visits.
    3. Personnel office.
    4. Sewer lines and connections.
    5. Spill protection measures.
15. Desirable features of available portable samplers include
    1. A rinse cycle for washing sample bottles.
    2. Automatic purging of lines before and after collecting a sample.
    3. Direct analysis of total suspended solids.
    4. Flexibility to collect samples at various time intervals.
    5. Sensor to find location of representative samples in sewer.
16. Samples are stored at 4°C in order to
    1. Freeze the sample.
    2. Melt the ice in the sample.
    3. Reduce biological activity in the sample.
    4. Reduce the pH of the sample.
    5. Reduce the rate of chemical reactions in the sample.

17. Flows should be measured from an industry in order to
    1. Calculate the quantities of pollutants discharged.
    2. Check compliance with pretreatment requirements.
    3. Determine which flow meter works best.
    4. Measure toxic gases released.
    5. Prepare accurate and equitable billing calculations.

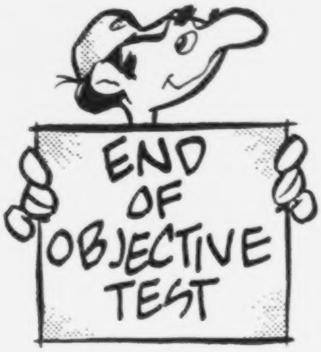
18. Industrial wastewater quality indicators that may be continuously monitored include
    1. Floatable solids.
    2. pH.
    3. Settleable solids.
    4. Specific conductance.
    5. Temperature.

19. Hazards that may be found in equipment storage areas include
    1. Chemicals stored in the same room as the equipment.
    2. Hydrogen gas produced by the charging of a lead-acid battery.
    3. Improperly marked reagent bottles.
    4. Items on the floor in normal traffic patterns.
    5. Items protruding from shelves.

20. What types of continuous monitoring and alarm systems are commonly available?
    1. BOD
    2. Explosive atmosphere (L.E.L.)
    3. High water level or flow
    4. Oxygen deficiency
    5. pH

21. Which of the following actions would you consider taking if a solvent was discovered in the wet well of your treatment plant?
    1. Divert solvent to holding basin if available
    2. Increase feed to digesters
    3. Keep personnel clear of area until safe to enter
    4. Provide extra ventilation to wet well
    5. Remove solvent by incineration in wet well

22. Which of the following actions would you consider taking if your treatment plant received a high temperature waste?
    1. If a trickling filter plant, try increasing recirculation rates
    2. If an activated sludge plant, try increasing aeration rates or oxygen supply
    3. Try cooling the waste at the headworks
    4. Try prechlorinating in collection system to reduce septic conditions
    5. Try stopping high temperature discharges at source



APPENDIX A

INDUSTRIAL SEWER-USE PERMIT APPLICATION

Source: Water Quality Division,
Department of Public Works,
Sacramento County,
Sacramento, California

INDUSTRIAL SEWER USE PERMIT APPLICATION

____________________ SANITATION DISTRICT

PAGE 1
GENERAL
(Instructions on reverse)

DISTRICT USE
SUP # __________
AP # __________
CP # __________
SIC # __________

1. NAME OF BUSINESS ____________________
2. ADDRESS OF PREMISES ____________________
3. OWNER OF BUSINESS ____________________
4. OWNER'S ADDRESS (Street) ____________________
   (City) __________ (Zip) __________
5. OWNER OF PROPERTY (IF DIFFERENT) ____________________
6. PROPERTY OWNER'S ADDRESS (Street) ____________________
   (City) __________ (Zip) __________
7. SEND SEWER BILLS TO: ☐ BUSINESS (1&2); ☐ BUSINESS OWNER (3&4); ☐ PROPERTY OWNER (5&6)
8. PERSON TO CONTACT ABOUT THIS APPLICATION __________ Phone __________
9. DESCRIPTION OF BUSINESS ____________________
10. RATE BASIS: ________ UNIT ________ QUANTITY
11. WASTEWATER GENERATING OPERATIONS: ____________________
12. SEASONAL VARIATIONS ____________________
13. ARE ANY OF THE FOLLOWING MATERIALS USED OR STORED ON THE PREMISES?

    1. Flammable or explosive materials. 2. Acid, alkaline, or corrosive material. 3. Pesticides or toxic material such as Aldrin, Dieldrin, Benzidine, Cadmium, Cyanide, DDD, DDE, DDT, Endrin, Mercury, PCB's, Toxaphene, Etc. 4. Oil, grease or solvents. 5. Metal solutions. 6. Phenols. 7. Large amounts of soaps or detergents. 8. Radioactive material. 9. Dyes.

☐ NO ☐ YES (if yes, please give description, and the approximate quantities used and/or stored.)

14. PERSON TO CONTACT IN AN EMERGENCY ____________________
    TITLE __________ Phone __________ Emergency No. __________

INSTRUCTIONS FOR COMPLETING PAGE 1

1. ENTER NAME OR TITLE OF BUSINESS.

2. ENTER FULL STREET ADDRESS OF BUILDING OR PREMISES PRODUCING THE WASTEWATER.

3. ENTER NAME OF INDIVIDUAL OR FIRM THAT IS THE OWNER OF THE BUSINESS.

4. ENTER MAILING ADDRESS OF OWNER OF BUSINESS.

5. ENTER NAME OF LEGAL OWNER OF PROPERTY UPON WHICH THE BUSINESS IS LOCATED, IF IT IS DIFFERENT THAN THE OWNER OF THE BUSINESS.

6. ENTER MAILING ADDRESS OF PROPERTY OWNER.

7. INDICATE WHERE SEWER BILLS SHOULD BE SENT. (UNLESS OTHERWISE INDICATED, THE BILLS WILL BE SENT TO THE PROPERTY OWNER).

8. IDENTIFY PERSON WHO IS THOROUGHLY FAMILIAR WITH THE FACTS REPORTED ON THESE FORMS AND MAY BE CONTACTED BY THE DISTRICT.

9 DESCRIBE THE PRINCIPAL ACTIVITY ON THE PREMISES, SUCH AS FOOD CANNING, BANK, ETC.

10. DETERMINE FROM TABLE BELOW WHICH UNIT WOULD BE APPLICABLE FOR THIS TYPE OF BUSINESS AND THE NUMBER OF UNITS. IF, FOR EXAMPLE, THE BUSINESS IS A MARKET, ENTER "AREA" FOR UNIT. THEN ENTER THE NUMBER OF SQUARE FEET IN THE STORE FOR QUANTITY.

BUSINESS	UNIT	BUSINESS	UNIT
Auto dealerships	Area (s.f.)	Market	Area (s.f.)
Bakeries	Area (s.f.)	Medical, Dental	Area (s.f.)
Banks and financial	Area (s.f.)	Mortuaries	Slumber rooms
Barber/beauty shops	Chairs	Offices	Area (s.f.)
Bars	Area (s.f.)	Places of Worship	Area (s.f.)
Bowling alleys	Lanes	Public agencies	Area (s.f.)
Car wash (full service)	Flow*	Rest/convalescent homes	Beds
Car wash (self service)	Stalls	Restaurants	Area (s.f.)
Dry cleaners	Area (s.f.)	Retail stores	Area (s.f.)
Garages	Bays	Schools	Attendance
Halls, Lodges	Area (s.f.)	Service stations	Pumps
Health studio, Gym	Area (s.f.)	Theaters	Seats
Hotel, Motel	Sleeping Rooms	Used car lots	Fixture units
Laundry (self service)	Machines	Warehouses	Area (s.f.)
Laundry (commercial)	Flow*	Others	Flow*

*estimate number of gallons of wastewater discharged each month

11. DESCRIBE WASTEWATER GENERATING PROCESS OCCURING ON THE PREMISES, INCLUDING PLANT OPERATIONS, RAW MATERIALS USED, CHEMICALS USED, AND ANY VARIATIONS IN DISCHARGE VOLUMES.

12. INDICATE WHETHER THE BUSINESS ACTIVITY IS CONTINUOUS THROUGHOUT THE YEAR OR IF IT IS SEASONAL. DESCRIBE THE SEASONAL VARIATION, LISTING MONTHS OF SEASONAL ACTIVITY.

13. LIST SIGNIFICANT RAW MATERIALS USED OR STORED ON PREMISES AND INDICATE DURATION OF STORAGE. INCLUDE ALL HAZARDOUS, POISONOUS, OR TOXIC MATERIALS EVEN IF THEY ARE KEPT ON PREMISES ONLY OCCASIONALLY. NEGLECT MATERIALS USED IN LABORATORY OR QUALITY CONTROL OPERATIONS. IF QUANTITIES IN INVENTORY VARY, SELECT AN AVERAGE AMOUNT OR GIVE RANGES. USE ADDITIONAL SHEETS IF NECESSARY.

14. GIVE NAME, TITLE, AND TELEPHONE NUMBER(S) OF A RESPONSIBLE PERSON WHO CAN BE CONTACTED IN CASE OF AN EMERGENCY (e.g. SPILLING OF A TOXIC MATERIAL)

INDUSTRIAL SEWER USE PERMIT APPLICATION

PAGE 2
LAYOUT

______________________ SANITATION DISTRICT

(Instructions on reverse)

SITE PLAN OF PREMISES

INSTRUCTIONS FOR COMPLETING PAGE 2

DRAW A SITE PLAN SHOWING LOCATION OF ALL PERTINENT BUILDINGS, SHEDS, WAREHOUSES, LOADING AND UNLOADING FACILITIES, FENCES, PROPERTY LINES, STREETS AND ROADS. INDICATE ALL SEWERS, STORM DRAINS, DRAINAGE DITCHES, MANHOLES, SAMPLING AND MONITORING LOCATIONS, WATER LINES AND METERS, AND SHOW THE SIZES OF THESE ITEMS. SHOW ALL POINTS OF CONNECTION TO THE PUBLIC SEWER AND DRAIN LINES. INDICATE SCALE AND NORTH ARROW. USE ADDITIONAL SHEETS IF NECESSARY. (BUILDING AND/OR SITE PLANS ACCEPTABLE TO THE DISTRICT MAY BE SUBSTITUTED FOR THIS FORM.)

INDUSTRIAL SEWER USE PERMIT APPLICATION

________________________ SANITATION DISTRICT

PAGE 3
WASTEWATER DATA
(Instructions on reverse)

1. WATER SOURCE
   - ☐ PRIVATE WELL
   - ☐ PUBLIC (METERED)
   - ☐ PUBLIC (UNMETERED)
   - ☐ OTHER ________________

2. WASTEWATER FLOW RATE TO SEWER:

PEAK HOURLY	MAX. DAILY	AVERAGE DAILY
________ (gal/hour)	________ (gal/day)	________ (gal/day)

3. DO YOU WISH PERMISSION TO DISCHARGE ANY OF THE FOLLOWING

	YES	NO
1. More than 50,000 gallons per day	☐	☐
2. A "slug" (more than five times the normal flow or strength for longer than 15 minutes)	☐	☐
3. A concentration of BOD or suspended solids in excess of 300 mg/l, or COD in excess of 500 mg/l	☐	☐
4. More than 3000 lbs of BOD or suspended solids, or 5000 lbs. of COD per day	☐	☐
5. Animal or vegetable derived oil or grease in excess of 300 mg/l, or petroleum derived oil or grease in excess of 100 mg/l	☐	☐
6. pH between 5.0 and 6.0, or higher than 9.0 (less than 5.0 is prohibited)	☐	☐
7. Metals, metal pickling wastes or plating solutions, phenols or other taste or odor producing substances, or soap or detergent	☐	☐
8. Temperature over 160° F maximum, or 120°F average	☐	☐
9. Stormwater, cooling water, etc., which is polluted or otherwise unacceptable for discharge into storm drains or natural outlets	☐	☐
10. Garbage (except from homes or restaurants)	☐	☐
11. Radioactive waste	☐	☐
12. Pool water or waste	☐	☐
13. Materials which cause unusual amounts of inert suspended solids (e.g. soil solids), dissolved solids (e.g. sodium chloride), or discoloration (e.g. dyes)	☐	☐
14. Discharges regulated by the EPA	☐	☐

If any are marked "YES", give details of each in "REMARKS" below, or attach sheet.
NOTE: THESE ITEMS MAY BE DISCHARGED ONLY IF SPECIFICALLY APPROVED.

4. ATTACH SHEET DESCRIBING ANY PRETREATMENT USED OR PLANNED.

5. REMARKS:

INSTRUCTIONS FOR COMPLETING PAGE 3

1. INDICATE WHERE WATER USED ON THE PREMISES IS OBTAINED.

2. LIST TOTAL DISCHARGES FROM PREMISES TO EACH SEPARATE SEWER.

   PEAK HOURLY - Indicate expected maximum flow in a one-hour period at any time in the year. Do not include batch discharges.

   MAXIMUM DAILY - Indicate expected maximum flow during a 24 hour period.

   AVERAGE DAILY - Estimate the flow during an average 24 hour period.

3. THESE ITEMS ARE REGULATED AND MAY BE DISCHARGED ONLY WITH THE SPECIFIC PERMISSION OF THE DISTRICT. INDICATE WHETHER YOU ANTICIPATE DISCHARGING THESE. IF SO, GIVE DETAILS IN "REMARKS" (#5).

4. DESCRIBE, ON A SEPARATE SHEET, ANY PRETREATMENT GIVEN THE WASTEWATER BEFORE IT IS DISCHARGED INTO THE SEWER. THE TREATMENT FACILITY SHOULD BE DESCRIBED IN SUFFICIENT DETAIL TO ENABLE AN ESTIMATION OF ITS EFFECTIVENESS.

5. GIVE ANY DETAILS REQUIRED BY #3. ALSO PROVIDE ANY INFORMATION ABOUT YOUR OPERATION THAT YOU FEEL MIGHT HAVE AN EFFECT ON THE SEWERAGE SYSTEM.

INDUSTRIAL SEWER USE PERMIT APPLICATION

PAGE 4

_________________ SANITATION DISTRICT CERTIFICATION

(Instructions on reverse)

WARNING – DISCHARGE OF SUBSTANCES INTO THE PUBLIC SEWER IS REGULATED BY LAW AND IS SUBJECT TO CIVIL AND CRIMINAL PENALTIES. IF YOU ANTICIPATE DISCHARGING ANYTHING OTHER THAN NORMAL DOMESTIC SEWAGE, YOU ARE ADVISED TO READ THE "SEWER USE ORDINANCE" ADOPTED BY THE BOARD OF DIRECTORS OF THE DISTRICT.

The Sewer Use Ordinance prohibits any discharge which would cause a hazard or interfere with the operation of the District's facilities, or would result in contamination, nuisance, or pollution of public waterways (refer to the ordinance for wording). In addition, the ordinance specifically prohibits the discharge to public sewers of the following:

PROHIBITED DISCHARGES – (BRIEF DESCRIPTION, see Sect. 6.4, Regional Sewer Use Ordinance,for full description):

1. Unpolluted storm or other waters.
2. Wastewater having pH lower than 5.0, or other corrosive properties.
3. Certain pesticides and other toxic pollutants.
4. Solid or viscous substances capable of causing an obstruction to the flow in sewers, or other interference with the proper operation or maintenance of the sewerage system.
5. Wastes which cannot be treated by the District's processes.
6. Materials prohibited by the EPA.

NOTE – A SEWER USE PERMIT PERTAINS ONLY TO THE DISCHARGE OF WASTEWATER INTO THE PUBLIC SEWERAGE SYSTEM . CONNECTION TO THE PUBLIC SEWER, AND THE INSTALLATION OR MODIFICATION OF ON-SITE PLUMBING, REQUIRES SEPARATE PERMITS.

CERTIFICATION: I certify that the information contained herein is true and correct to the best of my knowledge.

Signature ______________________ Date ______________

Name (type or print) ______________________ Title ______________

SEWER USE PERMIT

The above named applicant is hereby authorized to use the public sewerage system subject to the following conditions:

1. Compliance with applicable sewer use ordinances
2. Payment of all applicable fees and charges
3.

The applicant shall report to the Water Quality Division any changes (permanent or temporary) to the premises or operations that could significantly change the quality or volume of the discharge, or deviate from the conditions under which this permit is granted. This permit is not transferable.

LOCAL APPROVAL

Signed ______________________ Date ______________

INSTRUCTIONS FOR COMPLETING PAGE 4

CERTIFICATION:

The application must be signed and dated by an officer, employee, or other agent of the business who has legal authority to bind the applicant business. Also type or print the name and title of the person signing the application.

RETURN THE APPLICATION TO:

Industrial Waste Section
Water Quality Division

* *

Do not complete the portion below the line. The Water Quality Division will determine what conditions will be applied to the permit, then will sign and return the permit to the applicant.

APPENDIX B

SAMPLE SEWER-USE ORDINANCE

Source: U.S. Environmental Protection Agency

ORDINANCE NO. ____________

AN ORDINANCE establishing rules and regulations for the discharge of wastewaters into the wastewater treatment system of the City of ________________________; and

WHEREAS, the Federal Water Pollution Control Act Amendments of 1972, P.L. 92-500 (hereinafter referred to as the "Act") have resulted in an unprecedented program of cleaning up our Nation's waters; and

WHEREAS, this City has already made and will continue to make a substantial financial investment in its wastewater treatment system to achieve the goals of the Act; and

WHEREAS, this City seeks to provide for the use of its wastewater treatment system by industries served by it without damage to the physical facilities, without impairment of their normal function of collecting, treating and discharging domestic wastewater, and without the discharge by this City's wastewater treatment system of pollutants which would violate the discharge allowed under its National Pollutant Discharge Elimination System (NPDES) permit and the applicable rules of all governmental authorities with jurisdiction over such discharges;

NOW, THEREFORE, BE IT ORDAINED AND ENACTED by the City Council of the City of ______________________, County of ______________________, State of ______________________, as follows:

SECTION 1: DEFINITIONS

Unless the context specifically indicates otherwise, the following terms as used in this Ordinance, shall have the meanings hereinafter designated:

(a) *"BIOCHEMICAL OXYGEN DEMAND"* (BOD) means the quantity of oxygen utilized in the biochemical oxidation of organic matter under standard laboratory procedure in five (5) days at 20°C, expressed in terms of weight and concentration (milligrams per liter).

(b) *"COOLING WATER"* means the water discharged from any use such as air conditioning, cooling or refrigeration, during which the only pollutant added to the water is heat.

(c) *"COMPATIBLE POLLUTANT"* means BOD, suspended solids, pH and fecal coliform bacteria, and such additional pollutants as are now or may be in the future specified and controlled in this City's NPDES permit for its wastewater treatment works where said works have been designated and used to reduce or remove such pollutants.

(d) *"DIRECTOR/("SUPERINTENDENT")* means the (director/superintendent of wastewater treatment system/of water pollution control/or public works) of this City or the duly appointed deputy, agent or representative.

(e) *"DOMESTIC WASTES"* means liquid wastes (i) from the non-commercial preparation, cooking and handling of food or (ii) containing human excrement and similar matter from the sanitary conveniences of dwellings, commercial buildings, industrial facilities, and institutions.

(f) *"GARBAGE"* means solid wastes from the domestic and commercial preparation, cooking and dispensing of food, and from the handling, storage and sale of food.

(g) *"INCOMPATIBLE POLLUTANT"* means any pollutant which is not a "compatible pollutant" as defined in this section.

(h) *"INDUSTRIAL WASTEWATER"* means the liquid wastes resulting from the processes employed in industrial, manufacturing, trade or business establishments, as distinct from domestic wastes.

(i) *"NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM"* (NPDES) means the program for issuing, conditioning and denying permits for the discharge of pollutants from point sources into the navigable waters, the contiguous zone and the oceans pursuant to Section 402 of the Act.

(j) *"PERSON"* means any individual, firm, company, partnership, corporation, association, group or society, and includes the State of ________________________, and agencies, districts, commissions and political subdivisions created by or pursuant to State law.

(k) *"pH"* means the logarithm of the reciprocal of the concentration of hydrogen ions in grams per liter of solution.

(l) *"PRETREATMENT"* means application of physical, chemical and biological processes to reduce the amount of pollutants in or alter the nature of the pollutant properties in a wastewater prior to discharging such wastewater into the publicly owned wastewater treatment system.

(m) *"PRETREATMENT STANDARDS"* means all applicable Federal rules and regulations implementing Section 307 of the Act, as well as any nonconflicting State or local standards. In cases of conflicting standards or regulations, the more stringent thereof shall be applied.

(n) *"SIGNIFICANT INDUSTRIAL USER"* means any industrial user of the City's wastewater treatment system whose flow exceeds (1) (50,000) gallons per day, or (ii) (five (5)) percent of the daily capacity of the treatment system.

(o) *"STORM WATER"* means any flow occurring during or immediately following any form of natural precipitation and resulting therefrom.

(p) *"SUSPENDED SOLIDS"* means the total suspended matter that floats on the surface of, or is suspended in, water, wastewater or other liquids, and which is removable by laboratory filtering.

(q) *"UNPOLLUTED WATER"* is water not containing any pollutants limited or prohibited by the effluent standards in effect, or water whose discharge will not cause any violation of receiving water quality standards.

(r) *"USER"* means any person who discharges, causes or permits the discharge of wastewater into the City's wastewater treatment system.

(s) *"USER CLASSIFICATION"* means a classification of user based on the 1972 (or subsequent) edition of the Standard Industrial Classification (SIC) Manual prepared by the Office of Management and Budget.

(t) *"WASTEWATER"* means the liquid and water-carried industrial or domestic wastes from dwellings, commercial buildings, industrial facilities, and institutions, together with any groundwater, surface water, and storm water that may be present, whether treated or untreated, which is discharged into or permitted to enter the City's treatment works.

(u) "*WASTEWATER TREATMENT SYSTEM*" (system) means any devices, facilities, structures, equipment or works owned or used by the City for the purpose of the transmission, storage, treatment, recycling, and reclamation of industrial and domestic wastes, or necessary to recycle or reuse water at the most economical cost over the estimated life of the system, including intercepting sewers, outfall sewers, sewage collection systems, pumping, power, and other equipment, and their appurtenances; extensions, improvements, remodeling, additions, and alterations thereof; elements essential to provide a reliable recycled supply such as standby treatment units and clear well facilities; and any works, including site acquisition of the land that will be an integral part of the treatment process or is used for ultimate disposal of residues resulting from such treatment.

(v) Terms not otherwise defined herein shall be as adopted in the latest edition of *STANDARD METHODS FOR THE EXAMINATION OF WATER & WASTEWATER*, published by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation.

SECTION 2: PROHIBITIONS AND LIMITATIONS OF WASTEWATER DISCHARGES

(a) *PROHIBITIONS ON WASTEWATER DISCHARGES.* No person shall discharge or deposit or cause or allow to be discharged or deposited into the wastewater treatment system any wastewater which contains the following:

(1) *OILS AND GREASE.* (A) Oil and grease concentrations or amounts from industrial facilities violating Federal pretreatment standards. (B) Wastewater from industrial facilities containing floatable fats, wax, grease or oils (Optional: (C) Wax, grease or oil concentrations of mineral origin of more than (   ) mg/*L* whether emulsified or not, or containing substances which may solidify or become viscous at temperatures between 32° and 150°F (0° and 65°C) at the point of discharge into the system.) (Optional: (D) Total fat, wax, grease or oil concentrations of more than (   ) mg/*L*, whether emulsified or not, or containing substances which may solidify or become viscous at temperatures between 32° and 150°F (0° and 65°C) at the point of discharge into the system.)

(2) *EXPLOSIVE MIXTURES.* Liquids, solids or gases which by reason of their nature or quantity are, or may be, sufficient either alone or by interaction with other substances to cause fire or explosion or be injurious in any other way to the sewerage facilities or to the operation of the system. At no time shall two successive readings on an explosion hazard meter, at the point of discharge into the sewer system, be more than five percent (5%) nor any single reading over ten percent (10%) of the Lower Explosive Limit (L.E.L.) of the meter. Prohibited materials include, but are not limited to, gasoline, kerosene, naphtha, benzene, toluene, zylene, ethers, alcohols, ketones, aldehydes, peroxides, chlorates, perchlorates, bromates, carbides, hydrides and sulfides.

(3) *NOXIOUS MATERIAL.* Noxious or malodorous solids, liquids or gases, which, either singly or by interaction with other wastes, are capable of creating a public nuisance or hazard to life, or are or may be sufficient to prevent entry into a sewer for its maintenance and repair.

(4) *IMPROPERLY SHREDDED GARBAGE.* Garbage that has not been ground or comminuted to such a degree that all particles will be carried freely in suspension under flow conditions normally prevailing in the public sewers, with no particle greater than one-half (½) inch in any dimension.

(5) *RADIOACTIVE WASTES.* Radioactive wastes or isotopes of such half-life or concentration that they do not comply with regulations or orders issued by the appropriate authority having control over their use and which will or may cause damage or hazards to the sewerage facilities or personnel operating the system.

(6) *SOLID OR VISCOUS WASTES.* Solid or viscous wastes which will or may cause obstruction to the flow in a sewer, or otherwise interfere with the proper operation of the wastewater treatment system. Prohibited materials include, but are not limited to, grease, uncomminuted garbage, animal guts or tissues, paunch manure, bones, hair, hides or fleshings, entrails, whole blood, feathers, ashes, cinders, sand, spent lime, stone or marble dust, metal, glass, straw, shavings, grass clippings, rags, spent grains, spent hops, waste paper, wood, plastic, tar, asphalt residues, residues from refining or processing of fuel or lubricating oil, and similar substances.

(7) *EXCESSIVE DISCHARGE RATE.* Wastewaters at a flow rate or containing such concentrations or quantities of pollutants that exceeds for any time period longer than fifteen (15) minutes more than five (5) times the average twenty-four (24) hour concentration, quantities or flow during normal operation and that would cause a treatment process upset and subsequent loss of treatment efficiency.

(8) *TOXIC SUBSTANCES.* Any toxic substances in amounts exceeding standards promulgated by the Administrator of the United States Environmental Protection Agency pursuant to Section 307(a) of the Act, and chemical elements or compounds, phenols or other taste or odor-producing substances, or any other substances which are not susceptible to treatment or which may interfere with the biological processes or efficiency of the treatment system, or that will pass through the system.

(9) *UNPOLLUTED WATERS.* Any unpolluted water including, but not limited to, water from cooling systems or of stormwater origin, which will increase the hydraulic load on the treatment system.

(10) *DISCOLORED MATERIAL.* Wastes with objectionable color not removable by the treatment process.

(11) *CORROSIVE WASTES.* Any waste which will cause corrosion or deterioration of the treatment system. All wastes discharged to the public sewer system must have a pH value in the range of (6) to (9) standard unit. Prohibited materials include, but are not limited to, acids, sulfides, concentrated chloride and fluoride compounds and substances which will react with water to form acidic products.

(b) *LIMITATIONS ON WASTEWATER DISCHARGES.* (Use either Option A or Option B.)

(Option A — General Limitations)

No person shall discharge or convey, or permit or allow to be discharged or conveyed, to a public sewer any wastewater containing pollutants of such character or quantity that will:

(1) Not be susceptible to treatment or interfere with the process or efficiency of the treatment system.

(2) Constitute a hazard to human or animal life, or to the stream or water course receiving the treatment plant effluent.

(3) Violate pretreatment standards.

(4) Cause the treatment plant to violate its NPDES permit or applicable receiving water standards.

(Option B — Specific Limitations)

The following are the maximum concentrations of pollutants allowable in wastewater discharges to the wastewater treatment system. Dilution of any wastewater discharge for the purpose of satisfying these requirements shall be considered a violation of this Ordinance.

Pollutant	**Concentration (mg/L) or Mass Limitation (kg/kg)**
Arsenic	(Options: See, e.g., Federal Guidelines; State and Local Pretreatment Programs, Volume I, Section C)
Barium	
Boron	
Cadmium	
Chromium (Total)	
Chromium (Trivalent)	
Chromium (Hexavalent)	
Chlorinated Hydrocarbons	
Copper	
Cyanide	
Iron	
Lead	
Manganese	
Mercury	
Nickel	
Phenolic Compounds	
Phosphorus	
Selenium	
Silver	
Surfactants	
Zinc	
pH	
Temperature	Not over 150°F (except where higher temperatures are permitted by law).

(c) *SPECIAL AGREEMENTS.* Nothing in this Section shall be construed as preventing any special agreement or arrangement between the City and any user of the wastewater treatment system whereby wastewater of unusual strength or character is accepted into the system and specially treated subject to any payments or user charges as may be applicable.

SECTION 3: CONTROL OF PROHIBITED WASTES

(a) *REGULATORY ACTIONS.* If wastewaters containing any substance described in Section 2 of this Ordinance are discharged or proposed to be discharged into the sewer system of the City or to any sewer system tributary thereto, the Director and (Corporation Counsel/City Attorney) may take any action necessary to:

(1) Prohibit the discharge of such wastewater.

(2) Require a discharger to demonstrate that in-plant modifications will reduce or eliminate the discharge of such substances in conformity with this Ordinance.

(3) Require pretreatment, including storage facilities, or flow equalization necessary to reduce or eliminate the objectionable characteristics or substances so that the discharge will not violate these rules and regulations.

(4) Require the person making, causing or allowing the discharge to pay any additional cost or expense incurred by the City for handling and treating excess loads imposed on the treatment system.

(5) Take such other remedial action as may be deemed to be desirable or necessary to achieve the purpose of this Ordinance.

(b) *SUBMISSION OF PLANS.* Where pretreatment or equalization of wastewater flows prior to discharge into any part of the wastewater treatment system is required, plans, specifications and other pertinent data or information relating to such pretreatment or flow-control facilities shall first be submitted to the Director for review and approval. Such approval shall not exempt the discharge or such facilities from compliance with any applicable code, ordinance, rule, regulation or order of any governmental authority. Any subsequent alterations or additions to such pretreatment or flow-control facilities shall not be made without due notice to and prior approval of the Director.

(c) *PRETREATMENT FACILITIES OPERATIONS.* If pretreatment or control of waste flows is required, such facilities shall be maintained in good working order and operated as efficiently as possible by the owner or operator at his own cost and expense, subject to the requirements of these rules and regulations and all other applicable codes, ordinances, and laws.

(d) *ADMISSION TO PROPERTY.* Whenever it shall be necessary for the purposes of these rules and regulations, the Director, upon the presentation of credentials, may enter upon any property or premises at reasonable times for the purpose of (1) copying any records required to be kept under the provisions of this Ordinance, (2) inspecting any monitoring equipment or method, and (3) sampling any discharge of wastewater to the treatment works. The Director may enter upon the property at any hour under emergency circumstances.

(e) *PROTECTION FROM ACCIDENTAL DISCHARGE.* Each industrial user shall provide protection from accidental discharge of prohibited materials or other wastes regulated by this Ordinance. Facilities to prevent accidental discharge of prohibited materials shall be provided and maintained at the owner or operator's own cost and expense. Detailed plans showing facilities and operating procedures to provide this protection shall be submitted to the Director for review, and shall be approved by him before construction of the facility. Review and approval of such plans and operating procedures shall not relieve the industrial user from the responsibility to modify the facility as necessary to meet the requirements of this Ordinance.

(f) *REPORTING OF ACCIDENTAL DISCHARGE.* If, for any reason, a facility does not comply with or will be unable to comply with any prohibition or limitations in this Ordinance, the facility responsible for such discharge shall immediately notify the Director so that corrective action may be taken to protect the treatment system. In addition, a written report addressed to the Director detailing the date, time and cause of the accidental discharge, the quantity and characteristics of the discharge and corrective action taken to prevent future discharges, shall be filed by the responsible industrial facility within five (5) days of the occurrence of the noncomplying discharge.

SECTION 4: INDUSTRIAL WASTEWATER MONITORING AND REPORTING

(a) *DISCHARGE REPORTS.*

(1) Every significant industrial user shall file a periodic Discharge Report at such intervals as are designated by the Director. The Director may require any other industrial users discharging or proposing to discharge into the treatment system to file such periodic reports.

(2) The discharge report shall include, but, in the discretion of the Director, shall not be limited to, nature of process, volume, rates of flow, mass emission rate, production quantities, hours of operation, concentrations of controlled pollutants or other information which relates to the generation of waste. Such reports may also include the chemical constituents and quantity of liquid materials stored on site even though they are not normally discharged. In addition to discharge reports, the

Director may require information in the form of (Industrial Discharge Permit Applications and (optional)) self-monitoring reports.

(b) *RECORDS AND MONITORING*

(1) All industrial users who discharge or propose to discharge wastewaters to the wastewater treatment system shall maintain such records of production and related factors, effluent flows, and pollutant amounts or concentrations as are necessary to demonstrate compliance with the requirements of this Ordinance and any applicable State or Federal pretreatment standards or requirements.

(2) Such records shall be made available upon request by the Director. All such records relating to compliance with pretreatment standards shall be made available to officials of the U. S. Environmental Protection Agency upon demand. A summary of such data indicating the industrial user's compliance with this Ordinance shall be prepared (quarterly) (optional) and submitted to the Director.

(3) The owner or operator of any premises or facility discharging industrial wastes into the system shall install at his own cost and expense suitable monitoring equipment to facilitate the accurate observation, sampling, and measurement of wastes. Such equipment shall be maintained in proper working order and kept safe and accessible at all times.

(4) The monitoring equipment shall be located and maintained on the industrial user's premises outside of the building. When such a location would be impractical or cause undue hardship on the user, the Director may allow such facility to be constructed in the public street or sidewalk area, with the approval of the public agency having jurisdiction over such street or sidewalk, and located so that it will not be obstructed by public utilities, landscaping or parked vehicles.

(5) When more than one user can discharge into a common sewer, the Director may require installation of separate monitoring equipment for each user. When there is a significant difference in wastewater constituents and characteristics produced by different operations of a single user, the Director may require that separate monitoring facilities be installed for each separate discharge.

(6) Whether constructed on public or private property, the monitoring facilities shall be constructed in accordance with the Director's requirements and all applicable construction standards and specifications.

(c) *INSPECTION, SAMPLING AND ANALYSIS.*

(1) *COMPLIANCE DETERMINATION.* Compliance determinations with respect to *SECTION 2* prohibitions and limitations may be made on the basis of either instantaneous grab samples or composite samples of wastewater. Composite samples may be taken over a 24-hour period, or over a longer or shorter time span, as determined necessary by the Director to meet the needs of specific circumstances.

(2) *ANALYSIS OF INDUSTRIAL WASTEWATERS.* Laboratory analysis of industrial wastewater samples shall be performed in accordance with the current edition of "Standard Methods," "Methods for Chemical Analysis of Water and Waste" published by the U. S. Environmental Protection Agency or the "Annual Book of Standards, Part 23, Water, Atmospheric Analysis" published by the American Society for Testing and Materials. Analysis of those pollutants not covered by these publications shall be performed in accordance with procedures established by the (State Department of Environmental Health).

(3) *SAMPLING FREQUENCY* (Optional). Sampling of industrial wastewater for the purpose of compliance determination with respect to *SECTION 2* prohibitions and limitations will be done at such intervals as the Director may designate. However, it is the intention of the Director to conduct compliance sampling or to cause such sampling to be conducted for all major contributing industries at least once in every (1 year) (optional) period.

SECTION 5: INDUSTRIAL DISCHARGE PERMIT SYSTEM (OPTIONAL)

(a) *WASTEWATER DISCHARGE PERMITS REQUIRED.* All significant industrial users proposing to connect to or discharge into any part of the wastewater treatment system must first obtain a discharge permit therefore. All existing significant industrial users connected to or discharging to any part of the City system must obtain a wastewater discharge permit within ninety (90) (optional) days from and after the effective date of this Ordinance.

(b) *PERMIT APPLICATION.* Users seeking a wastewater discharge permit shall complete and file with the Director an application on the form prescribed by the Director, and accompanied by the application fee. In support of this application, the user shall submit the following information:

(1) Name, address, and SIC number of applicant.

(2) Volume of wastewater to be discharged.

(3) Wastewater constituents and characteristics including, but not limited to, those set forth in *SECTION 2* of this Ordinance as determined by a reliable analytical laboratory.

(4) Time and duration of discharge.

(5) Average and (30) (optional) minute peak wastewater flow rates, including daily, monthly and seasonal variations, if any.

(6) Site plans, floor plans, mechanical and plumbing plans and details to show all sewers and appurtenances by size, location and elevation.

(7) Description of activities, facilities and plant processes on the premises including all materials and types of materials which are, or could be, discharged.

(8) Each product produced by type, amount, and rate of production.

(9) Number and type of employees, and hours of work.

(10) Any other information as may be deemed by the director to be necessary to evaluate the permit application.

The Director will evaluate the data furnished by the user and may require additional information. After evaluation and acceptance of the data furnished, the Director may issue a wastewater discharge permit subject to terms and conditions provided herein.

(c) *PERMIT CONDITIONS.* Wastewater discharge permits shall be expressly subject to all provisions of this Ordinance and all other regulations, user charges and fees established by the City. The conditions of wastewater discharge permits shall be uniformly enforced in accordance with this Ordinance, and applicable State and Federal regulations. Permit conditions will include the following:

(1) The unit charge or schedule of user charges and fees for the wastewater to be discharged to the system.

(2) The average and maximum wastewater constituents and characteristics.

(3) Limits on rate and time of discharge or requirements for flow regulations and equalization.

(4) Requirements for installation of inspection and sampling facilities, and specifications for monitoring programs.

(5) Requirements for maintaining and submitting technical reports and plant records relating to wastewater discharges.

(6) Daily average and daily maximum discharge rates, or other appropriate conditions when pollutants subject to limitations and prohibitions are proposed or present in the user's wastewater discharge.

(7) Compliance schedules.

(8) Other conditions to ensure compliance with this Ordinance.

(d) *DURATION OF PERMITS.* Permits shall be issued for a specific time period, not to exceed (five) (optional) years. A permit may be issued for a period of less than (one) (optional) year, or may be stated to expire on a specific date. If the user is not notified by the Director (30) (optional) days prior to the expiration of the permit, the permit shall automatically be extended for (x) months. The terms and conditions of the permit may be subject to modification and change by the (responsible official) during the life of the permit, as limitations or requirments as identified in Section 2 are modified and changed. The user shall be informed of any proposed changes in the permit at least (30) (optional) days prior to the effective date of change. Any changes or new conditions in the permit shall include a reasonable time schedule for compliance.

(e) *TRANSFER OF A PERMIT.* Wastewater discharge permits are issued to a specific user for a specific operation. A wastewater discharge permit shall not be reassigned or transferred or sold to a new owner, new user, different premises, or a new or changed operation.

(f) *REVOCATION OF PERMIT.* Any user who violated the following conditions of the permit or of this Ordinance, or of applicable State and Federal regulations, is subject to having the permit revoked. Violations subjecting a user to possible revocation of the permit include, but are not limited to, the following:

(1) Failure of a user to accurately report the wastewater constituents and characteristics of the discharge;

(2) Failure of the user to report significant changes in operations, or wastewater constituents and characteristics;

(3) Refusal of reasonable access to the user's premises for the purpose of inspection or monitoring; or

(4) Violation of conditions of the permit.

SECTION 6: ENFORCEMENT PROCEDURES

(a) *NOTIFICATION OF VIOLATION.* Whenever the Director finds that any person has violated or is violating the Ordinance, or any prohibition, limitation or requirement contained herein, the Director may serve upon such person a written notice stating the nature of the violation and providing a reasonable time, not to exceed thirty (30) days, for the satisfactory correction thereof.

(b) *SHOW CAUSE HEARING.*

(1) If the violation is not corrected by timely compliance, the Director may order any person who causes or allows an unauthorized discharge to show cause before the (hearing authority) why service should not be terminated. A notice shall be served on the offending party, specifying the time and place of a hearing to be held by the (hearing authority) regarding the violation, and directing the offending party to show cause before (said authority) why an order should not be made directing the termination of service. The notice of the hearing shall be served personally or by registered or certified mail (return receipt requested) at least (ten) days before the hearing. Service may be made on any agent or officer of a corporation.

(2) The (hearing authority) may itself conduct the hearing and take the evidence, or may designate any of its members or any officer or employee of the (assigned department) to:

(A) Issue in the name of the (hearing authority) notices of hearings requesting the attendance and testimony of witnesses and the production of evidence relevant to any matter involved in any such hearings.

(B) Take the evidence.

(C) Transmit a report of the evidence and hearing, including transcripts and other evidence, together with recommendations to the (hearing authority) for action thereon.

(3) At any public hearing, testimony taken before the hearing authority or any person designated by it, must be under oath and recorded stenographically. The transcript, so recorded, will be made available to any member of the public or any part to the hearing upon payment of the usual charges therefor.

(4) After the (hearing authority) has reviewed the evidence, it may issue an order to the party responsible for the discharge directing that, following a specified time period, the sewer service be discontinued unless adequate treatment facilities, devices or other related appurtenances shall have been installed or existing treatment facilities, devices or other related appurtenances are properly operated, and such further orders and directives as are necessary and appropriate.

(c) *LEGAL ACTION.* Any discharge in violation of the substantive provisions of this Ordinance or an Order of the (hearing authority) shall be considered a public nuisance. If any person discharges sewage, industrial wastes or other wastes into the City treatment system contrary to the substantive provisions of this Ordinance or any Order of the (hearing authority), the (Corporation Counsel/City Attorney) shall commence an action for appropriate legal and/or equitable relief in the (Circuit) Court of this County.

SECTION 7: PENALTY; COSTS

Any person who is found to have violated an Order of the (hearing authority) or who willfully or negligently failed to comply with any provisions of this Ordinance, and the orders, rules and regulations issued hereunder, shall be fined not less than (One Hundred Dollars) (optional) nor more than (One Thousand Dollars) (optional) for each offense. Each day on which a violation shall occur or continue shall be deemed a separate and distinct offense. In addition to the penalties provided herein, the City may recover reasonable attorneys' fees, court costs, court reporters' fees and other expenses of litigation by appropriate suit at law against the person found to have violated this Ordinance or the orders, rules and regulations issued hereunder.

SECTION 8: SAVINGS CLAUSE

If any provision, paragraph, word, section or article of this Ordinance is invalidated by any court of competent jurisdiction, the remaining provisions, paragraphs, words, sections, and articles shall not be affected and shall continue in full force and effect.

SECTION 9: CONFLICT

All ordinances and parts of ordinances inconsistent or conflicting with any part of this Ordinance are hereby repealed to the extent of such inconsistency or conflict.

SECTION 10: EFFECTIVE DATE

This Ordinance shall be in full force and effect (Option A) from and after its passage, approval and publication, as provided by law. (Option B)
on the ____ day of ____________________, 19____.

INTRODUCED the ____ day of ______________, 19____.

FIRST READING: ____________________, 19____.
SECOND READING: ____________________, 19____.

PASSED THIS ____ day of ______________, 19____.

AYES:
NAYS:
ABSENT:
NOT VOTING:
APPROVED by me this ____ day of __________, 19____.

____
MAYOR
ATTEST: ____________________ (Seal) City Clerk
Published the ____ day of ____________________, 19____.

APPENDIX C

STANDARD FORM A — MUNICIPAL

Section IV. Industrial Waste Contribution to Municipal System

FORM APPROVED
OMB No. 158–R0100

FOR AGENCY USE

STANDARD FORM A–MUNICIPAL

SECTION IV. INDUSTRIAL WASTE CONTRIBUTION TO MUNICIPAL SYSTEM

Submit a description of each major industrial facility discharging to the municipal system, using a separate Section IV for each facility description. Indicate the 4 digit Standard Industrial Classification (SIC) Code for the industry, the major product or raw material, the flow (in thousand gallons per day), and the characteristics of the wastewater discharged from the industrial facility into the municipal system. Consult Table III for standard measures of products or raw materials. (see instructions)

1. **Major Contributing Facility** (see instructions)

Name 401a ______________________

Number& Street 401b ______________________

City 401c ______________________

County 401d ______________________

State 401e ______________________

Zip Code 401f ________

2. **Primary Standard Industrial Classification Code** (see instructions) 402 ________

3. **Principal Product or Raw Material** (see instructions)

			Quantity		Units (See Table III)
Product	403a	403c		403e	
Raw Material	403b	403d		403f	

4. **Flow** Indicate the volume of water discharged into the municipal system in thousand gallons per day and whether this discharge is intermittent or continuous.

404a ________ thousand gallons per day

404b ☐ Intermittent (int) ☐ Continuous (con)

5. **Pretreatment Provided** Indicate if pretreatment is provided prior to entering the municipal system

405 ☐ Yes ☐ No

6. **Characteristics of Wastewater** (see instructions)

406a	Parameter Name							
	Parameter Number							
406b	Value							

EPA Form 7550–22 (7–73)
GPO 865-706

This section contains 1 page.

APPENDIX D

SAFETY ORDERS FOR BATTERY CHARGING

Source: California Administrative Code (Safety Orders)

SAFE PROCEDURES FOR BATTERY CHARGING

Changing and Charging Storage Batteries. Battery charging installations shall be located in areas designated for that purpose. Employees assigned to work with storage batteries shall be instructed in emergency procedures such as dealing with accidental acid spills.

The area shall be adequately ventilated to prevent concentrations of flammable gases exceeding 20 percent of the lower explosive limit, and to prevent harmful concentration of mist from the electrolyte.

While batteries are being charged, smoking and open flame shall be prohibited in battery charging area and signs stating that prohibition shall be posted in the area.

Electrolyte (acid or base, and distilled water) for battery cells shall be mixed in a well ventilated room. Acid or base shall be poured gradually into the water while stirring. Water shall never be poured into concentrated (greater than 75 percent) acid solutions.

When charging batteries, the vent caps should be kept in place but loosened to avoid electrolyte spray. Care shall be taken to assure that vent caps are functioning.

Fire extinguishing equipment adequate to cope with the hazards which may be encountered shall be provided and maintained close at hand.

Eye protection devices which provide side as well as frontal eye protection for employees shall be provided when measuring storage battery specific gravity or handling electrolyte, and the employer shall ensure that such devices are used by the employees. The employer shall also ensure that acid resistant gloves and aprons shall be worn for protection against spattering.

CHAPTER 6

INDUSTRIAL WASTE TREATMENT PROCESSES

by

Mark Acerra

Paul Amodeo

Dan Campbell

Tony Diaper

John Gonzales

Jim Palmer

Robert Wills, Jr.

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OBJECTIVES

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Industrial waste pretreatment and treatment processes covered in Chapter 6 include:

1. Flotation,
2. Screening and microscreening,
3. Neutralization,
4. Coagulation and precipitation, and
5. Adsorption (activated carbon).

Biological treatment of industrial wastes is covered in Chapter 2, Section 2.5, "Industrial Waste Treatment."

Following completion of Chapter 6, you should be able to do the following:

1. Identify various types of processes,
2. Safely operate and maintain the processes,
3. Start-up, operate and shut down the processes,
4. Develop an operational strategy for the processes,
5. Understand and interpret laboratory data and make appropriate adjustments in the treatment processes,
6. Understand and recognize abnormal conditions and become aware of troubleshooting necessary under normal operation,
7. Prepare a maintenance program and schedule for the processes, and
8. Review the plans and specifications for the processes.

GLOSSARY

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

ABSORPTION (ab-SORP-shun) ABSORPTION

Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACID ACID

(1) A substance that tends to lose a proton. (2) A substance that dissolves in water with the formation of hydrogen ions. (3) A substance containing hydrogen which may be replaced by metals to form salts.

ACIDITY ACIDITY

The capacity of water or wastewater to neutralize bases. Acidity is expressed in milligrams per liter of equivalent calcium carbonate. Acidity is not the same as pH because water does not have to be strongly acidic (low pH) to have a high acidity. Acidity is a measure of how much base can be added to a liquid without causing a great change in pH.

ADSORPTION (add-SORP-shun) ADSORPTION

The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.

AGGLOMERATION (a-GLOM-er-A-shun) AGGLOMERATION

The growing or coming together of small scattered particles into larger flocs or particles which settle rapidly. Also see FLOC.

ALKALI ALKALI

Any of certain soluble salts, principally of sodium, potassium, magnesium, and calcium, that have the property of combining with acids to form neutral salts and may be used in chemical processes such as water or wastewater treatment.

ALKALINITY (Al-ka-LIN-ity) ALKALINITY

The capacity of water or wastewater to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.

ANION ANION

A negatively charged ion in an electrolyte solution, attracted to the anode under the influence of electric potential.

BAFFLE BAFFLE

A flat board or plate, deflector, guide or similar device constructed or placed in flowing water, wastewater or slurry systems to cause more uniform flow velocities, to absorb energy, and to divert, guide or agitate liquids.

BASE BASE

A compound which dissociates (separates) in aqueous solution to yield hydroxyl ions.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

BLINDING BLINDING

The clogging of the filtering medium of a microscreen or a vacuum filter when the holes or spaces in the media become sealed off due to grease or the material being filtered.

BUFFER BUFFER

A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BUFFER ACTION BUFFER ACTION

The action of certain ions in solution in opposing a change in hydrogen-ion concentration.

BUFFER CAPACITY BUFFER CAPACITY

A measure of the capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water or wastewater for offering a resistance to changes in pH.

BUFFER SOLUTION BUFFER SOLUTION

A solution containing two or more substances which, in combination, resist any marked change in pH following addition of moderate amounts of either strong acid or base.

CHEMICAL EQUIVALENT CHEMICAL EQUIVALENT

The weight in grams of a substance that combines with or displaces one gram of hydrogen. Chemical equivalents usually are found by dividing the formula weight by its valence.

CHEMICAL PRECIPITATION CHEMICAL PRECIPITATION

(1) Precipitation induced by addition of chemicals. (2) The process of softening water by the addition of lime or lime and soda ash as the precipitants.

CLARIFICATION (KLAIR-i-fi-KAY-shun) CLARIFICATION

Any process or combination of processes the main purpose of which is to reduce the concentration of suspended matter in a liquid.

CLARIFIER (KLAIR-i-fire) CLARIFIER

Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time, during which the heavier solids settle to the bottom and the lighter materials will float to the water surface.

COAGULANT (co-AGG-you-lent) COAGULANT

A chemical that causes very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COAGULANT AID COAGULANT AID

Any chemical or substance used to assist or modify coagulation.

COAGULATION (co-AGG-you-LAY-shun) COAGULATION

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

CONTINUOUS PROCESS CONTINUOUS PROCESS

A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.

DEFINING DEFINING

A process that arranges the activated carbon particles according to size. This process is also used to remove small particles from granular contactors to prevent excessive head loss.

DETENTION TIME DETENTION TIME

The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DIAPHRAGM PUMP DIAPHRAGM PUMP

A pump in which a flexible diaphragm, generally of rubber or equally flexible material, is the operating part. It is fastened at the edges in a vertical cylinder. When the diaphragm is raised suction is exerted, and when it is depressed, the liquid is forced through a discharge valve.

DOCTOR BLADE DOCTOR BLADE

A blade used to remove any excess solids that may cling to the outside of a rotating screen.

EFFLORESCENCE (EF-low-RESS-ense) EFFLORESCENCE

The powder or crust formed on a substance when moisture is given off upon exposure to the atmosphere.

EFFLUENT (EF-lu-ent) EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

ELECTROLYTE (ELECT-tro-LIGHT) ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

END POINT END POINT

Samples are titrated to the end point. This means that a chemical is added, drop by drop, to a sample until a certain color change (blue to clear, for example) occurs which is called the *END POINT* of the titration. In addition to a color change, an end point may be reached by the formation of a precipitate or the reaching of a specified pH. An end point may be detected by the use of an electronic device such as a pH meter. The completion of a desired chemical reaction.

EQUALIZING BASIN EQUALIZING BASIN

A holding basin in which variations in flow and composition of a liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit. Also called a balancing reservoir.

FLOC FLOC

Groups or clumps of bacteria and particles or coagulants and impurities that have come together and formed a cluster. Found in aeration tanks, secondary clarifiers and chemical precipitation processes.

FLOCCULATION (FLOCK-you-LAY-shun) FLOCCULATION

The gathering together of fine particles to form larger particles.

GATE GATE

A movable watertight barrier for the control of a liquid in a waterway.

HYDROGEN-ION CONCENTRATION (H^+) HYDROGEN-ION CONCENTRATION (H^+)

The weight of hydrogen ion in moles per liter of solution. Commonly expressed as the pH value, which is the logarithm of the reciprocal of the hydrogen-ion concentration.

$$pH = \log \frac{1}{(H^+)}$$

HYDROLYSIS (hi-DROL-e-sis) HYDROLYSIS

The addition of water to the molecule to break down complex substances into simpler ones.

HYGROSCOPIC (HI-grow-SKOP-ic) HYGROSCOPIC

A substance that absorbs or attracts moisture from the air.

IMPELLER IMPELLER

A rotating set of vanes designed to impart rotation of a mass of fluid.

IMPELLER PUMP IMPELLER PUMP

Any pump wherein the water is moved by the continuous application of power from some rotating mechanical source.

INFLUENT (IN-flu-ent) INFLUENT

Wastewater or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process, or treatment plant.

IONIC CONCENTRATION IONIC CONCENTRATION

The concentration of any ion in solution, generally expressed in moles per liter.

IONIZATION IONIZATION

The process of adding electrons to, or removing electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, and nuclear radiation can cause ionization.

LIQUEFACTION (LICK-we-FACK-shun) LIQUEFACTION

The conversion of large solid particles of sludge into very fine particles which either dissolve or remain suspended in wastewater.

MICRON (MY-kron) MICRON

A unit of length. One millionth of a meter or one thousandth of a millimeter. One micron equals 0.00004 of an inch.

MICROSCREEN MICROSCREEN

A device with a fabric straining media with openings usually between 2 and 60 microns. The fabric is wrapped around the outside of a rotating drum. Wastewater enters the open end of the drum and flows out through the rotating screen cloth. At the highest point of the drum, the collected solids are backwashed by high-pressure water jets into a trough located within the drum.

NEUTRALIZATION (new-trall-i-ZAY-shun) NEUTRALIZATION

Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.

NONCORRODIBLE NONCORRODIBLE

A material that resists corrosion and will not be eaten away by wastewater or chemicals in wastewater.

OVERFLOW RATE OVERFLOW RATE

One of the guidelines for the design of settling tanks and clarifiers in treatment plants.

$$\text{Overflow Rate, gpd/sq ft} = \frac{\text{Flow, gallons/day}}{\text{Surface Area, sq ft}}$$

pH (PEA-A-ch) pH

pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically pH is the logarithm (base 10) of the reciprocal of the hydrogen-ion concentration.

$$\text{pH} = \text{Log}\,\frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is most acid, 14 most basic, and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

PHENOLPHTHALEIN ALKALINITY PHENOLPHTHALEIN ALKALINITY

A measure of the hydroxide ions plus one half of the normal carbonate ions in aqueous suspension. Measured by the amount of sulfuric acid required to bring the water to a pH value of 8.3, as indicated by a change in color of phenolphthalein. It is expressed in milligrams per liter of calcium carbonate.

ROTARY PUMP ROTARY PUMP

A type of displacement pump consisting essentially of elements rotating in a pump case which they closely fit. The rotation of these elements alternately draws in and discharges the water being pumped. Such pumps act with neither suction or discharge valves, operate at almost any speed, and do not depend on centrifugal forces to lift the water.

SCREEN SCREEN

A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SOLUTE SOLUTE

The substance dissolved in a solution. A solution is made up of the solvent and the solute.

SUSPENDED SOLIDS SUSPENDED SOLIDS

(1) Solids that either float on the surface or are suspected in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as Total Suspended Solids Dried at 103-105°C.

TITRATE (TIE-trate) TITRATE

To *TITRATE* a sample, a chemical solution of known strength is added on a drop-by-drop basis until a color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical solution to completion of the reaction as signaled by the end point.

TURBID TURBID

Having a cloudy or muddy appearance.

TURBIDITY UNITS (TU) TURBIDITY UNITS (TU)

Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water, they are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.

ULTRAFILTRATION ULTRAFILTRATION

A membrane filtration process used for the removal of organic compounds in an aqueous (watery) solution.

WEIR **WEIR**

(1) A wall or plate placed in an open channel and used to measure the flow. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

ULTRIFICATION

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

(Lesson 1 of 6 Lessons)

6.0 NEED TO TREAT INDUSTRIAL WASTE

by Dan Campbell

6.00 Uses of Water by Industry

Most industrial processes either require water or are made more efficient by the use of water for one purpose or another. As the water is being used, some of the other materials used in the industrial process may become mixed in with the water. That part of the water which is not re-used by the industry is discharged as industrial wastewater.

Figure 6.1 shows some of the major potential uses of water by industry. At "A" the water is taken from its source. This could be taken directly from a surface water source such as a river or lake, directly from a groundwater source including various types of wells, or from a community water supply. Note that whatever the source, water used by industry may need to be treated by the industry before it is suitable for use.

The water may then be used by industries in a number of ways, as shown at "B." In many cases, water is necessary to the process itself. An obvious example is laundry, but other examples include the pulp and paper industry, dairies, breweries, distilleries and others. In many cases, water is used to make processing of other materials easier or more efficient. In any of these cases, this is referred to as "process water." Another use of water by industry is for the transport of materials to, through, and from the industrial process, such as in vegetable processing. As shown in Figure 6.1, water also is used for cooling, as for example in refineries and steel mills. Many industries use washwater for both products (fruit and vegetable processing, some metal finishing operations) and facilities (canneries, dairies).

After being put to one or more of the above uses, the water may be recycled for repeated use if its characteristics have not been changed so much it becomes unsuitable "C." This may be done directly or the water may be treated to make re-use possible. When the water is treated, materials are removed. These materials may then be a disposal problem "E." Also, these materials may have value to the industry or other industries either in the same or a different process. An example of this is the use of wastes from steel pickling by municipal wastewater treatment plants "D." When it is uneconomical for the industry to recycle this water, it becomes industrial wastewater "F."

In almost all cases, industrial wastewater is not suitable for direct discharge to a receiving water, but must first be treated to remove pollutants. Figure 6.1 shows three possible alternatives for treatment of industrial wastewater:

(G) Discharge to a Publicly Owned Treatment Works (POTW) to be combined with municipal wastes and possibly wastes from other industries, treated, and returned to the environment;

(H) Pre-treatment by industry, followed by discharge to a POTW, as above; and

(I) Treatment by industry to the extent required before discharge to a receiving water.

Whatever scheme is used, the ultimate objective is the protection of the receiving water for protection of the public health and for the various uses of the receiving waters.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 448.

6.0A List four general uses of water by industries.

6.0B What are the three alternative arrangements possible for treating industrial wastewater?

6.01 Reasons for Treatment of Industrial Wastes

6.010 Dissolved and Suspended Wastes

During any of the four general uses of water by industry, the water may acquire waste materials. These may be in the form of "dissolved" matter, usually defined for wastewater purposes as those which will pass through a fine filter, or in the form of "suspended" matter, that is, particles which may settle to the bottom or float to the surface if given enough time. More frequently they are combinations of dissolved and suspended matter. Depending on the specific nature of the matter which is added, the characteristics of the water may be changed, thus affecting its potential for use.

An important basic concept is that water in the environment belongs to all of us, not to any individual or group. Individuals or groups are allowed to use water, but they must use it in such a way as not to interfere with its use by others with rights to use the water. Let's briefly examine some of the uses of water and some ways in which wastes can interfere with the use of water.

6.011 Drinking Water

Use of water for drinking and other domestic purposes is the most basic use of water and generally has priority over any competing use. There are many ways in which water can be rendered unsafe or unfit for drinking. These different types of contamination are discussed in the following paragraphs.

1. *BIOLOGICAL CONTAMINATION.* This problem usually stems from prior use of water to carry human wastes. Sanitary wastewater, domestic wastes, or simply sewage or wastewater are terms used to designate this category of wastes. Bacteria, viruses and other microorganisms are

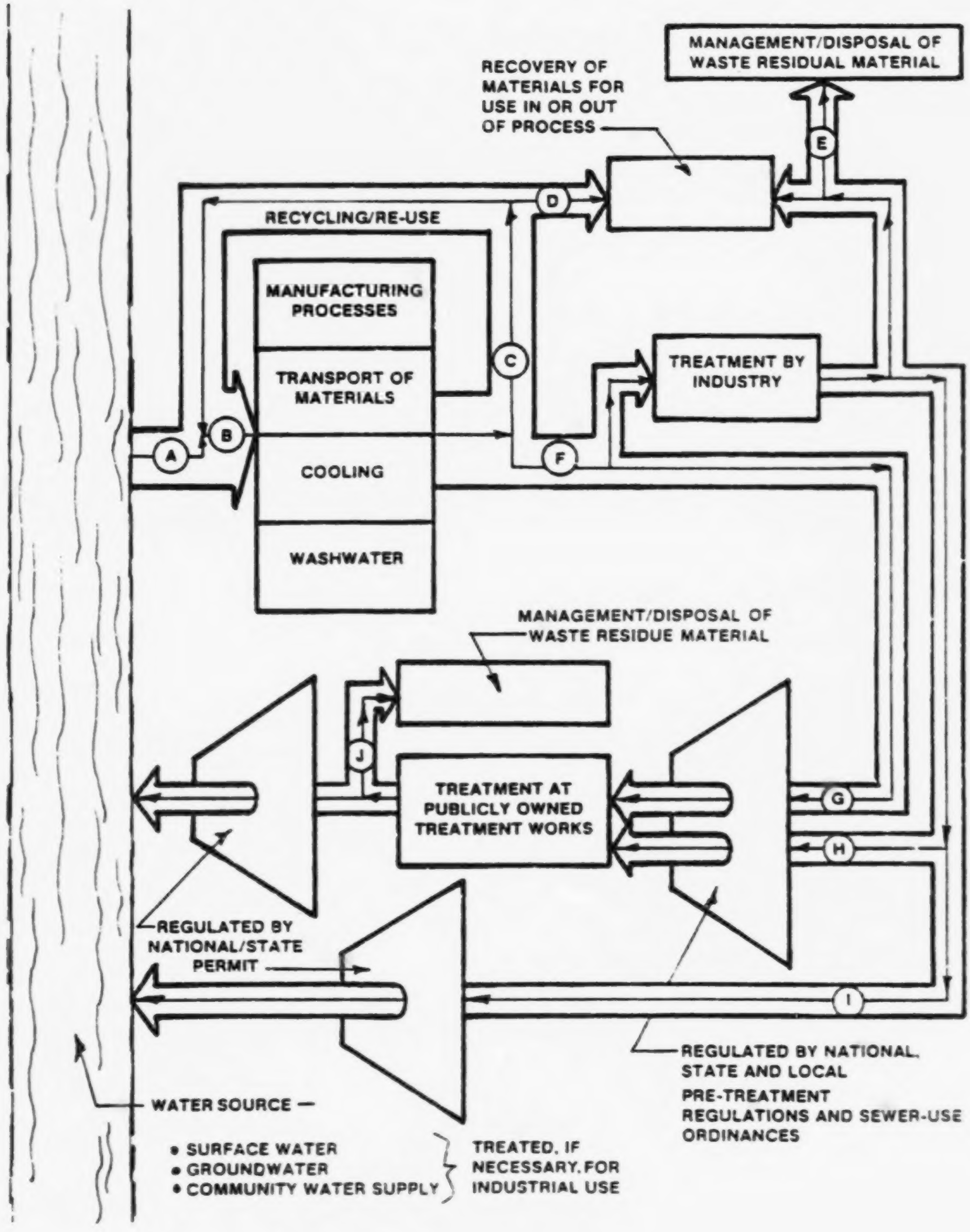

MANAGEMENT/DISPOSAL OF WASTE RESIDUAL MATERIAL
RECOVERY OF MATERIALS FOR USE IN OR OUT OF PROCESS
E
D
RECYCLING/RE-USE
MANUFACTURING PROCESSES
TRANSPORT OF MATERIALS
C
TREATMENT BY INDUSTRY
A
B
COOLING
F
WASHWATER
MANAGEMENT/DISPOSAL OF WASTE RESIDUE MATERIAL
J
TREATMENT AT PUBLICLY OWNED TREATMENT WORKS
G
H
REGULATED BY NATIONAL/STATE PERMIT
I
REGULATED BY NATIONAL, STATE AND LOCAL
PRE-TREATMENT REGULATIONS AND SEWER-USE ORDINANCES
WATER SOURCE —
• SURFACE WATER
• GROUNDWATER
• COMMUNITY WATER SUPPLY
TREATED, IF NECESSARY, FOR INDUSTRIAL USE

Fig. 6.1 Use of water by industry

excreted from the human body and other warm-blooded animals. Some of these organisms may cause disease if they are successful in completing or short-circuiting a cycle through wastewater treatment, discharge to the environment, and treatment for water supply, and are ingested by a human. In addition to sanitary wastewater, such mircoorganisms may reach environmental waters through stormwater as it washes the land of animal wastes and through certain industries, most notably slaughterhouses and tanneries.

Protection of human populations from this biological contamination has been the historical foundation for public wastewater treatment and water treatment, with disinfection being the particular process most involved. Where wastewater and water treatment are routine practices, diseases which might otherwise be transmitted through drinking water, such as typhoid, cholera and dysentery, are rare. Industries which may potentially discharge pathogenic organisms must be sure that their wastes are adequately disinfected.

2. *CHEMICAL CONTAMINATION.* This is potentially a whole host of problems, rather than a single, neat category. Depending on their nature and concentration, foreign chemicals in drinking water may produce sudden illness, or may produce long-term "chronic" illness which is not diagnosed for years, but which may have severe effects. This is not to say that all chemicals in water, even drinking water, are bad. Chlorine, for example, has been used for generations as a disinfectant, and its use has undoubtedly saved untold numbers of lives. We are now learning, however, that when combined with certain other chemicals, chlorine may cause long-term disease. This serves to emphasize that we are not free to use water to "wash away" compounds we are not sure what else to do with when we want to get rid of them. The problem is made even more complex because many of the compounds considered toxic are dangerous at even extremely low concentrations, measured as micrograms per liter or parts per billion. Imagine trying to find six black pingpong balls in a room filled with them and 999,999,994 white ones. This is equivalent to six parts per billion and roughly equivalent to 6 micrograms per liter. Some of the categories of chemical contamination are listed below:

   a. *TOXIC CHEMICALS* — A great variety of chemicals have toxic effects in drinking water. These range from simple chemical elements such as mercury, chromium, and other metals to compounds consisting of numbers of elements such as pesticides. From an industrial wastewater standpoint, the most likely source of this type of contamination is from the manufacturing processes in which these chemicals are either used or made and from in-plant spills and accidents.

   A number of recent episodes with toxic and potentially toxic chemicals points out that many of the dangers of toxic compounds are not even suspected at the time we begin using them.

   b. *CHEMICALS NOT NORMALLY TOXIC* — Many chemicals are not considered toxic in concentrations normally encountered, but may present other problems if present in drinking water. Oils and greases present in water supplies may pass through water treatment processes in concentrations high enough to cause tastes and odors. Inorganic salts in low concentrations are considered beneficial to water supplies. In higher concentrations, however, they present problems. Sulfate in high concentrations produces a laxative effect. Waters high in inorganic salts cause crusting or deposits on the insides of pipes, thus decreasing the capacity of the pipes.

3. *RADIOACTIVE CONTAMINATION.* Long-term health damage and even death could be caused by the presence of radioactive contaminants in drinking water.

4. *OTHER TYPES OF CONTAMINATION.* Other factors such as temperature, color, and turbidity, may be problems in water supplies. These factors may not cause health problems of themselves, but may cause people to use a different source of water which may be unsafe because the safe source is made unattractive.

6.012 Cooking Water

Water used for food preparation may be ingested, and of course the food is ingested. Consequently, the potential problems are very much like those listed above for drinking water.

6.013 Water-contact Recreation

Activities such as swimming and water skiing, in which the body has direct contact with the water, are referred to as water-contact recreation. Although the health risks from water-contact recreation are not as great as from drinking water, they are real. The most obvious forms of pollution interfering with water-contact recreation are those which make the water unappealing.

1. *BIOLOGICAL CONTAMINATION.* The most likely risk from biological contamination is that of eye, ear, and skin infection, although accidental ingestion of contaminated water is also a risk.
2. *CHEMICAL CONTAMINATION.* Ingestion is considered less of a problem due to the small volume which might be accidentally ingested. Acids and other chemicals, if present in water may cause irritation of the eyes and other sensitive parts of the body. There are many chemicals, such as some pesticides, that have toxic effects which are severe upon contact with the skin.
3. *OXYGEN-CONSUMING WASTES.* These wastes actually are a form of chemical pollution. However, this problem is so severe that it is considered a problem in its own right. Many organic or oxygen-consuming wastes may be discharged from dairies, breweries, distilleries, pharmaceutical manufacturing, fruit and vegetable processing, textile manufacturing, paper manufacturing, coke and gas industries and municipalities.

These types of wastes are actually treated in a stream or river by the action of the same microorganisms found in a treatment plant. In this treatment process, the organisms "breathe" the oxygen which is present in the water. If all the oxygen is gone, other microorganisms which can get their oxygen from compounds in the water continue the treatment process. The by-products of this latter type of treatment (anaerobic decomposition) produce unpleasant odors, colors and sludges that discourage water-contact recreation.

4. *INORGANIC ELEMENTS.* This also is a form of chemical pollution, but some types of inorganic elements such as phosphorus and nitrogen are nutrients that promote the growth of algae. Algae are bacteria which, under proper conditions, can multiply to such an extent in water that they interfere with water-contact recreation and other uses of the water. In sunlight, algae add oxygen to water, but in the absence of light and as they decay, dissolved oxygen is removed from the water. Algae reduce the clarity of water and give it a green color. Both of these items are considered undesirable from an esthetic standpoint. Phosphorus and nitrogen also promote the growth of larger vegetation such as aquatic weeds.
5. *SOLIDS AND VISIBLE POLLUTION.* Visible pollution obviously interferes with water-contact and other forms of water recreation. Floating solids, oil, and foam are potential contaminants from industry which would be in this category. Other types of solids may settle to the bottom of the water and form sludge beds. Organic material in the sludge beds decomposes, presenting the problems identified under "Oxygen-consuming Wastes."
6. *OTHER CONTAMINANTS.* Increased temperature in water decreases the amount of oxygen available and at the same time leads to an increasing rate of microorganism uptake of the oxygen which is present. This compounds the problems of oxygen-demanding wastes described above. Radiation poses a health hazard from contact in which the radioactive material may remain on the skin.

6.014 Water for Fish, Wildlife and Aquatic Vegetation

Water is necessary for all forms of life. The types of contamination described above, particularly with respect to drinking water, can interfere with the use of the water to support forms of life other than human. Many fish and other organisms are even more susceptible to damage from toxic materials than humans. Many states limit the amount of chlorine which can be added to wastewater effluent because of the sensitivity of aquatic life to chlorine. An additional problem is that some lower forms of life can accumulate some toxic materials. As fish and higher forms of life consume these smaller organisms, toxicity levels rise in the higher forms. This bioaccumulation magnifies the hazard both to the fish and other creatures higher in the food chain, including humans.

Fish also depend on the dissolved oxygen present in water for life. For this reason, many of the standards set for levels of dissolved oxygen in water are based on the needs of fish.

6.015 Non-body Contact Water Recreation

Boating and similar non-contact recreation activities are interfered with primarily by visible types of pollution. Fishing, of course, would depend on the suitability of water to support fish.

6.016 Agricultural Use

Water for irrigation should be reasonably free from biological contamination. Many chemicals, including some metals and inorganic salts will retard or prevent crop growth at certain concentrations and would be harmful for livestock.

6.017 Industrial Use

The suitability of water for industrial use depends largely on the industry in question. Water which is safe for drinking sometimes must receive additional treatment for certain industrial uses.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 448.

6.0C Name three ways in which water can be biologically contaminated.

6.0D What is the name of the process by which water that may be biologically contaminated is made safe?

6.0E What are the major potential sources of contamination of water by toxic materials?

6.0F Describe how oxygen-consuming wastes interfere with water use.

6.0G What are the potential uses of water with which toxicity may interfere?

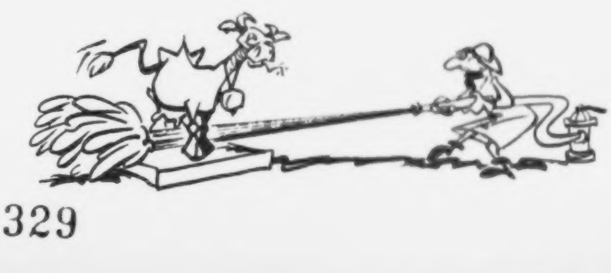
6.02 Types of Industrial Wastewater

Wastewaters produced by industries can be significantly different, even among industries making the same product, depending upon the process used. In this section, we'll describe some of the major water-using industries and the types of wastewater which they may produce. We'll also take a look at some of the major treatment processes which are commonly used for each type of wastewater, although these are discussed in detail in other chapters. If your plant uses a type of treatment process mentioned, you should take particular note of the chapter in which that treatment process is discussed.

6.020 Dairy Wastes

This is a classification given to wastes from a variety of milk-product installations, including receiving stations, bottling plants, cheese factories, and ice cream plants. Dairy processing plants typically produce a waste very high in BOD and solids. BOD values of dairy wastewater effluent are about 1,000 mg/liter but values up to 10,000 mg/liter are not uncommon. Sources of the waste are from the milk residue washed away in cleansing and from accidental spills. In addition to the high organic content of the waste, the wastes frequently arrive in large volumes over short periods of time (shock loads).

Normal treatment processes for dairy wastes include flow equalization (that is, storing what would be a shock load in a large tank and discharging it more uniformly to the treatment process), pre-treatment by chemical precipitation, and some form of biological treatment (activated sludge, trickling filter, rotating biological contactor). Nutrients may have to be added for microorganisms treating dairy wastes to produce the best results. See Chapter 2, Section 2.573, "Treatment of Dairy Wastes," for additional details.



6.021 Tannery Wastes

Tanning is the process of manufacturing leather from animal hides. A number of separate operations are involved in the tanning process. Each process has differing characteristics. The wastes are generally mixed in a controlled manner, allowed to chemically react and settle. The composite of these wastes is high in salt, BOD, and suspended solids. Flow is variable because tanning is accomplished in a batch process. This makes flow equalization helpful for effective treatment.

Combined tannery wastes can be expected to average up to 8,000 mg/liter of suspended solids and up to 1,000 mg/liter of BOD. Most of the BOD loading in tannery wastes can be expected from the de-hairing and soaking of the hides. The wastewater should be screened to remove as much of the coarse material as possible before subsequent treatment. After screening, the wastes can be treated biologically with trickling filters, rotating biological contactors, and/or activated sludge.

Particular problems with tannery wastes may stem from some of the process chemicals. The lime, used in the dehairing process, can build up and clog sewer lines as well as possibly clog trickling filter media. Chromic sulfate from the tanning process can interfere with digestion of sludge from wastewater treatment.

6.022 Pulp and Paper Wastes

Pulping is the process of recovering fiber from wood or other vegetable matter for subsequent processing into paper. In the process, between 10 and 50 percent of the raw material may be rejected. This, together with the high volume of water used in the process, the relatively high organic loading, and the natural resistance of the type of organic material in the wastes to biological oxidation, make treatment difficult. One of the most effective means of treatment is the recovery of materials. BOD ranges from 200 to 1,000 milligrams per liter are common. The suspended solids consist primarily of cellulose materials, bark, silt, dregs and grits from the pulping process and fillers, coatings and similar materials. The solids will usually settle readily. BOD reduction may be accomplished through this settling process to some extent and further through biological treatment, often in waste stabilization ponds. Other methods of treatment include chemical precipitation, activated sludge and lagooning. In the case of biological treatment, it may be necessary to add nutrients to the wastes for effective biological oxidation. In the manufacture of paper and paper products the pulp, either alone or in combination with recycled paper, is processed with various chemicals. The organic strength of the wastewater from paper manufacturing depends largely on the specific type of paper being produced. Average BOD and suspended solids concentrations could be expected to be similar to municipal wastewater, although some will be considerably more concentrated. Treatment through biological oxidation, such as activated sludge, should be effective for this type of wastewater, however, it may be necessary to practice control of the pH level of the wastes as well as the nutrient level. Refer to Chapter 2, "Activated Sludge," Section 2.55, "Pulp and Paper Mill Wastes," for additional details.

6.023 Meat Packing Wastes

Wastes from the meat packing industry actually stem from a number of operations within the industry. The principal operations are those related to stockyards, slaughter houses, and packing houses. Stockyard wastes consist principally of manure, hay, straw, and dirt. These wastes are high in organic materials and high in nutrients. Stockyard wastes are suitable for land disposal and should be segregated and hauled or piped away for that purpose. Slaughter house wastes can be categorized as those resulting from the killing of the animal and the preparation of the carcass. Principal wastes are the blood, grease, manure, body fluids, hair, flesh and fat particles. These wastes, in undiluted form, are extremely high in organic content. For example, blood has the highest BOD of any liquid meat processing material, that is, 400,000 mg/*L*. Paunch manure has a BOD of 100,000 mg/*L*. Therefore, unrecovered losses to the waste stream should be kept to a minimum.

Packing house wastes are those resulting from preparation of the carcass into a saleable product. Processes involved are smoking, cooking, curing, pickling, and sausage making. Wastes are principally grease, blood, and flesh and fat particles. Waste streams from slaughter houses and packing houses tend to be high in BOD, averaging 1,000 to 2,000 mg/*L* and high in suspended solids, averaging 500 to 1,500 mg/*L*. They will also contain high amounts of nitrogen and grease that will tend to have a neutral pH. Average water use in slaughter houses and packing houses is from 1,000 to 5,000 gallons (3,800 to 19,000 liters) of water per 1,000 pounds (455 kg) of live weight killed. Water conservation should be practiced because of the high pollutant characteristics of meat packing wastes. Recovery of much of the waste material for use as by-products often is economical. Such by-products include glue, soap, animal feed, and fertilizer.

Pretreatment of wastes in the meat packing industry often proves economical from the dual standpoints of recovery of the by-products and of reduced sewer-use charges. Pretreatment processes include flow equalization. This is usually economically advantageous because it permits smaller subsequent treatment units and averages the flow into the sewer which often minimizes user charges. Screening is another common pretreatment process because a great deal of the pollutional material in meat packing waters is in solid form. Screens should be checked frequently and cleaned as needed. Centrifuging is used to a lesser extent to remove residual grease and fine solids from waste streams. Another common type of pretreatment process is the practice of grease and suspended solids separation, either by gravity and/or dissolved air flotation. Gravity grease recovery systems can remove up to 30 percent of the BOD, 50 percent of the suspended solids and 60 percent of the grease from the waste stream. Gravity systems must be checked to be sure that baffles, weirs, and scum removal mechanisms are kept clean. From a safety consideration, regularly hose down all spills as there will be considerable grease which will become slippery if not removed. Dissolved air flotation systems will remove up to 35 percent of the BOD, 60 percent of the suspended solids and up to 90 percent of the grease from waste streams.

Following these pretreatment processes, a wide range or a combination of treatment systems is common. Meat packing wastes are suitable for treatment by anaerobic processes because of their characteristics. The temperature of the wastes is often from 85 to 95°F (29 to 35°C), it is high in BOD and suspended solids, contains a high content of fats and proteins, as well as nutrients. These are all characteristics required for successful anaerobic treatment. The most common types of anaerobic treatment used for the meat packing industry are anaerobic lagoons, which are deeper than aerobic or facultative lagoons. Anaerobic lagoons are commonly from 12 to 18 feet (3.6 to 5.4 m) deep. Effluents from anaerobic lagoons usually contain up to 100 mg/*L* of ammonia nitrogen. This concentration of ammonia nitrogen is toxic to most aquatic life. Anaerobic lagoons, therefore, need to be followed by an aerobic treatment system.

The second type of anaerobic treatment used in the meat packing industry is the anaerobic contact unit which is an anaerobic digester with mixing equipment and related settling tanks. About 12 hours of detention time is provided within the anaerobic digester.

Aerobic types of treatment which are used with success include lagoons (either aerated lagoons or oxidation ponds), activated sludge units, trickling filters or rotating biological contactors. Spray irrigation and overland runoff of treated wastes are also being used in the meat packing industry.

6.024 Fermentation Wastes

Fermentation is the name given to the breaking down of sugars and starches into simpler compounds by yeasts. The manufacture of bread, beer, wine, alcohol and penicillin are some of the processes using fermentation. The wastes resulting from the fermentation process include the unfermented portions of raw materials, waste liquor from the wet grain and yeast recovery and washwater from various parts of the process. Unfermented portions of raw materials are primarily insoluble solids which should be recovered and not discharged into sewers. Recovered solids are used as animal feed and in the manufacture of certain chemical products. Water use in the brewery industry is high, averaging up to 10 to 15 gallons of water for every gallon of beer produced. Cleaning of vats and process equipment produces most of the waste volume which will range from 500 to 1,500 mg/*L* of BOD. Wastes from the production of antibiotics are high in BOD. Some may be as high as 20,000 mg/*L*. Fermentation wastes are suitable for bio-oxidation if the pH level is controlled. The wastes will be acidic. Nutrient addition is usually necessary because the wastes are deficient in nitrogen and phosphorus. The most effective bio-oxidation processes for fermentation wastes are trickling filters and anaerobic digestion.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 448.

6.0H Dairy processing plants typically produce a waste very high in __________ and __________.

6.0I Why are flows of tannery wastes highly variable?

6.0J Why is the treatment of pulp and paper wastes considered difficult?

6.0K List three economical by-products from packing house wastes.

6.0L What is fermentation?

6.025 Fruit and Vegetable Processing Wastes

This is a highly diversified and widespread industry. Wastewater characteristics and treatment problems are also highly variable, depending upon the specific product and type of processing to which it is subjected. In general, the most significant problems encountered in the treatment of fruit and vegetable processing wastes are the seasonal nature of the processing and the nutrient deficiency commonly existing in the wastewater.

The specific processes commonly used within the industry include preliminary cleaning and preparation, blanching, canning (including pasteurization and cooling), and juicing. Preliminary cleaning and preparation includes conveyance of the fruit or vegetable. This may be accomplished either mechanically or hydraulically. Mechanical means of conveying include screw conveyors, belt conveyors and vibrating tables. Hydraulic means of conveyance include flow-through pipes and fluming, that is, flow in open channels. Hydraulic conveyance contributes to waste strength by the leaching of sugars, acids and starches as well as the washing of foreign matter from the surface.

There are actually a number of washes typical in the processing of any given fruit or vegetable. The initial washing removes soil, pesticides and other contaminants from the surface of the fruit or vegetable. Other washings in subsequent phases of the process remove additional process materials. The third preliminary preparation process is that of peeling. Use of hot lye peeling is common, followed by high pressure water spray. Since this process produces a high percentage of the cannery's pollution load, this first rinse should be segregated and treated separately. Blanching is the process of heating the product in water or steam for a short time. Other types of blanching are now being used, including hot air blanching and microwave blanching. Wet blanching leaches out nutrients while dry blanching preserves more of the vitamin value of the product and reduces wastewater volumes as much as 99 percent.

Canning as a process characteristically includes filling of the container with the product, pasteurization within the container and cooling of the container. Prior to the canning process, the product may be pumped, strained, and/or heated and may have additional materials such as spices, flavorings and preservatives added to it. The process of filling the container inevitably will result in spillage, whether the filling is done mechanically or by hand. Washing of the container adds to the wastewater stream. The filled container is then pasteurized and cooled, normally using large quantities of cooling water. This cooling water is normally clear and is suitable for reuse for additional cooling, washing, or fluming. The cooling water should not be allowed to mix with the wastewater because it is relatively unpolluted and the additional volume of water would then need to be subjected to treatment.

Many products are used to produce juice. Sources of wastes from the juicing process include dry, pressed pulp which should be treated as an organic solid waste, spent filter cake from clarification of juices which should also be treated as an organic solid waste, and water evaporated from the juice to concentrate it. This water is characteristically high in organic content.

The soundest approach to wastewater management in the fruit and vegetable industry, as in most industries, is that of waste prevention and reduction. A key element of this is the practice of good housekeeping and operational procedures. Each step of the process should be thoroughly examined for the purpose of reducing wastes and assuring that the minimum amount of water possible is used in each step. Spillage and breakage, in addition to reducing the amount of product which can be sold, adds to the wastewater treatment problem. Screens should be placed over all drains in a plant to prevent the unnecessary washing of solids into the wastewater stream. Whenever possible, high pressure — low volume sprays should be used for cleaning.

Flow meters should be installed so that unnecessarily high rates of use can be monitored and prevented. Automatic shut-offs, such as trigger nozzles, should be used. Plant staff should be educated to the proper use of water valves. They should be opened only as far as necessary, rather than being left totally open. Soak and wash tank overflows should be eliminated to the extent possible. Another aspect of waste prevention and reduction is the segregation of high concentration wastes for separate handling. Cooling waters can often be directly discharged or reused within the plant. If directly discharged, care must be taken that excess heat is not discharged to a stream.

Counter-flow washing as a process technique is often effectively used. In counter-flow washing, the flow of washwater is opposite to that of the product. In this way the cleanest water is washing the cleanest product. As the water moves along the product line, it picks up impurities as it moves toward the least clean end of the product line.

Another aspect of waste prevention and reduction is the actual change of process used. Although more drastic than any of the measures cited above, such a change will often be of economic benefit to the plant. Examples of process changes which have been applied are the substitution of dry, caustic, mechanical or abrasive drum peeling for hot lye peeling and air cooling instead of water cooling.

Treatment of fruit and vegetable processing wastes can be accomplished in a variety of ways. Screening, either with stationary, revolving or vibrating screens, can achieve high settleable solids and floating solids removal and sometimes up to 70 percent suspended solids removal. Screens should be installed as close as possible to the process generating the solids. Stationary screens will tend to remove only the coarser particles, whereas revolving and vibrating screens may reduce the waste load in terms of solids up to 50 percent. Screening will usually produce no significant effect on BOD, other than the BOD removed as suspended solids.

One form of pretreatment which is frequently necessary, particularly for root crops, is that of grit removal. Soil may make up a significant percentage of the weight of a root crop. Another treatment process frequently used is dissolved air flotation which may reduce the suspended solids load of the wastewater by as much as 80 percent. The organic solids removed in screening and dissolved air flotation can have a number of potential by-product uses. They may be further processed to make purees, vinegar or alcohol. They may be used for animal feed. Solids not used in such a fashion may be composted, landfilled, or otherwise disposed of in a suitable, sanitary manner.

As with many industrial processes, it is frequently necessary to equalize the wastewater flow in fruit and vegetable processing wastes because of the flow variation. Sedimentation is effective for treatment of some types of fruit and vegetable processing wastes and ineffective for others. Effectiveness depends upon the amount of settleable solids in the waste stream. Plain sedimentation is typically effective for treatment of wastewater from processing potatoes, tomatoes and carrots and ineffective for products such as apples, peas, peaches, and pears. Biological treatment of fruit and vegetable processing wastewater is technically feasible and frequently proves to be practical as typically 85 percent of the BOD in fruit and vegetable processing wastewater consists of dissolved organic matter. However, due to the seasonality of production and the characteristic nutrient deficiency in fruit and vegetable processing wastewater, biological treatment may not always be feasible. When feasible, biological treatment can be effective with trickling filters, activated sludge units, pure oxygen activated sludge units, and anaerobic filters. Typically it is necessary to add nutrients for effective biological treatment of fruit and vegetable processing wastewater. This may be done by mixing with domestic wastewater, or in extreme cases with anhydrous ammonia or ammonium sulfate. Sludge from the activated sludge process that has been applied to fruit and vegetable processing wastewater is difficult to dewater. One advantage of anaerobic filters as applied to the processing of fruit and vegetable wastewater is that they can be used effectively on an intermittent basis.

6.026 Textile Wastes

Textile manufacturing is the making of woven fabrics from either natural or synthetic fibers. Natural fibers are those such as wool, cotton and silk. Synthetic fibers are those such as rayon, acrylics or polyester. A primary source of wastes from natural fibers is the foreign matter present in the fibers such as dirt, grease and waxes. These are removed by boiling or scouring which generate considerable wastes. The main wastes from synthetics are the chemicals used in the processing of the synthetics. The scouring of wool produces the greatest waste load of any single process in the textile industry. Typically, 1,000 pounds of wool as sheared from the lamb will produce 600 pounds of natural impurities and 400 pounds of finished wool.

Cotton undergoes a process called sizing which is the strengthening of the thread to make it ready for weaving. The thread is then rinsed or desized to remove the waste starch of polyvinyl alcohol, which is the sizing medium. The cotton is then scoured with caustic to remove natural waxes and other impurities. These two processes yield approximately 80 percent of the waste load from a typical cotton mill. Textile mills dealing with synthetics generally have lower water usage and waste generation than those dealing with natural fibers. For example, nylon mills typically use 15,000 gallons of water per 1,000 pounds of cloth with a BOD loading of 40 to 50 pounds of BOD per 1,000 pounds of cloth produced. Cotton, on the other hand, typically requires well over 20,000 gallons of water per 1,000 pounds of cloth with the BOD loading of 50 to 200 pounds per 1,000 pounds of cloth. The BOD loading for wool is over 400 pounds per 1,000 pounds of cloth.

Typical treatment problems in the textile industry include those from lint, fibers and strings which clog pipes and equipment and collect on the sides of tanks and channels. The natural grasses found on the fibers and the soaps used in processing them produce a scum which is capable of producing strains and odors as it flows through the treatment process. Foam may be caused by the soaps and detergents used in processing the textiles. Textile wastes differ widely in pH. Basic wastes are generally less of a problem because they are easier to treat using biological processes. Acidic wastes can be neutralized by the addition of lime, caustic soda ash or ammonia. Wastes with a pH below 5.5 should never be allowed to enter a wastewater system because they will cause the corrosion of concrete and other structures in the treatment process. Another potential problem with textile wastes is that of variations in hydraulic flow. Unless the flow is equalized, periods of high flow will produce reduced treatment times and increased treatment costs. Periods of low flow may cause odors and other treatment problems. Some processes in the manufacture of textiles involve metals which may be toxic to treatment processes.

Effective treatment of textile wastes, as with most types of industrial wastes, begins in the manufacturing process itself. A variety of considerations in the manufacturing process will improve the capability for wastewater treatment. Such techniques include flow reduction, water reuse, waste segregation, process or material substitution, and good housekeeping. To treat textile wastes by screening, use either stationary, rotary or vibrating screens to remove lint and prevent clogging of pipes and equipment. The lint may also collect on the sides of tanks and channels yielding odor and other problems.

Equalization is frequently practiced in the treatment of textile wastes, usually to produce steady levels of BOD. Segregated wastes are usually equalized, that is, segregated into those which produced the greatest BOD loading. In cotton this is the desizing and scouring wastes; in wool, the scouring and wash after fulling wastes; and in polyester, the knitting oil scour wastes. Neutralization of the wastewater is also a common treatment technique. Neutralization is frequently accomplished by mixing of wastes of acidic and basic pHs. Other pretreatment techniques may include BOD reduction, particularly of segregated wastes, and chemical treatment for specific purposes, such as removal of metals or coagulation for removal of detergents. Subsequent treatment processes which have been used effectively in the textile industry include trickling filters, activated sludge, rotating biological contactors and chemical coagulation.

6.027 Petroleum Wastes

Wastes from the petroleum industry can be categorized as those resulting from oil production or oil refining. Brine is the principal waste from oil production. Brine may be disposed of by injection but caution must be exercised not to pollute groundwater. Brine may be disposed of into surface waters but this method will frequently necessitate compensation of downstream users of the surface water. Brine may also be treated by solar evaporation, dilution or chemical coagulation. Refinery wastes include acids, alkalies, sulfur compounds, phenols, and oil itself. Most of the water used in the refining industry is used for cooling, but even this may be contaminated by leakage. For this reason, effective wastewater control requires the reduction of leakage within the plant as well as other good housekeeping measures.

Treatment of petroleum wastes consists of separation of the oil, chemical coagulation and sedimentation, and biological treatment. See Chapter 2, Section 2.58, "Petroleum Refinery Wastes," for additional details.

6.028 Metal Finishing Wastes

Finishing refers to the improvement of the surface of the metal. This is usually accomplished by one or more of a variety of processes including cleaning, hardening, softening, roughing, smoothing, coating or plating. Finishing is done to improve corrosion resistance, durability, appearance, conductivity, or other physical characteristics of the metal. The most common finishing processes are steel, iron and copper pickling and electroplating. The metals most commonly plated are copper, cadmium, nickel, zinc, and chromium. From an industrial waste standpoint, precious metal electroplating is of secondary importance. Liquid wastes from the metal finishing industry are not normally high in volume but are potentially dangerous. Toxic materials included in metal finishing wastes are acids, chromium, zinc, copper, nickel, tin and cyanide. Other contaminants are alkaline cleaners, grease and oil. Specific sources of wastes from the metal finishing industry are waste process solutions (such as cleaners), acid solvents and plating solutions from accidental discharges of process solutions, and rinse water effluents.

Management of the metal finishing wastewater problem begins with consideration of in-plant process improvements. Considerable work has been done in this respect. One problem which has received much attention is that of dragout. As the product being finished is moved out of a processing tank, some of the solution in the tank is carried or dragged out with it. Among the techniques for minimizing drag-out are proper positioning of the article being finished, drip pans, and shaking and standing rinses with reuse of the rinse water. Metal finishing wastes are usually treated chemically because the contaminants are generally not only resistant to biological treatment but are frequently highly toxic to biological organisms. Some of the specific waste treatment processes include chlorination for alkaline wastes; oxidation and precipitation for cyanide; reduction neutralization for chromium wastes; and ion exchange and evaporation for recovery of valuable metals.

6.029 Coke Wastes

The manufacture of coke is accomplished by heating coal in the absence of air. Two thousand pounds of coal will yield about 1,400 ponds of coke with the remainder going into byproducts such as gases, tar and other materials. Wastes from coke manufacturing tend to be high in BOD and phenol content as well as containing ammonia creosols, sulfide and cyanide residuals. These wastes are usually pretreated to recover ammonia and either convert phenols to less objectionable materials or recover phenols. Treatment processes used are biological treatment, such as activated sludge or trickling filtration or physical treatment, such as steam stripping.

6.03 Solutions to Treating Industrial Wastes

This section has identified the problems associated with the treatment of various types of industrial wastes. If you have an industrial waste treatment problem, refer to the previous section for the treatment problems caused by the particular industry. Once you've identified the problem and the industry, refer to the appropriate sections in this chapter or chapters in this manual to solve the waste treatment problem. For example, if you are treating dairy wastes with an activated sludge plant and the problems are being caused by a nutrient deficiency, refer to Chapter 2, "Activated Sludge," Section 2.5, "Industrial Waste Treatment," to determine how much of which nutrients should be added. The procedures for solving a nutrient deficiency in an activated sludge plant could be applied to other biological treatment processes.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 448.

6.0M What are the two most significant problems encountered in the treatment of fruit and vegetable processing wastes?

6.0N What is one major advantage of anaerobic filters as applied to the processing of fruit and vegetable wastewater?

6.0O List five typical treatment problems in the textile industry.

6.0P What is the principal problem of wastes from the petroleum industry?

6.0Q List five toxic substances found in metal finishing wastes.

END OF LESSON 1 OF 6 LESSONS ON INDUSTRIAL WASTE TREATMENT

Please answer the discussion and review questions before continuing with Lesson 2.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 6 Lessons)

Write the answers to these questions in your notebook before continuing.

1. Identify one advantage and one limitation of the use of chlorine with wastewaters.
2. What problems could oils and greases cause in receiving waters used as a source for a drinking water supply?
3. If algae add oxygen to water in the presence of sunlight, then why are algae considered undesirable?
4. What treatment processes are commonly used to treat dairy wastes?
5. Why is pretreatment of wastes often practiced in the meat packing industry?
6. How could canning cooling waters be reused in a cannery?

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

(Lesson 2 of 6 Lessons)

6.1 FLOTATION by Jim Palmer

6.10 Process Analysis

6.100 Process Description

The dissolved air flotation system is based on the principle that the solubility of gases in a solution increases as the pressure on the solution increases. For an example, when 100 gallons (378 liters) of water is saturated with air at atmospheric pressure and at 67 degrees F (19.4°C), this volume contains approximately 0.25 cubic feet (7 liters) of air; when saturated at 30 *PSIG*[1] (2.1 kg/sq cm), this volume contains 0.75 cubic feet (21 liters) of air; when saturated at 50 psig (3.5 kg/sq cm), this volume contains 1.1 cubic feet (31 liters) of air; and so on. But when this pressurized volume is returned to atmospheric pressure, the dissolved air will return to its original 0.25 cubic feet (7 liters) of air per 100 gallons (378 liters). Therefore, if water saturated with air at 50 psig (3.5 kg/sq cm) is released to atmospheric pressure, it will release from solution 0.85 cubic feet (24 liters) of air per 100 gallons (378 liters) (1.1 cubic feet − 0.25 cubic feet or 31 liters − 7 liters). The released air forms microscopic bubbles which have the characteristic of rising to the surface of the water. The microscopic air bubbles form on and attach themselves to the suspended solids in the volume being treated as a *CONTINUOUS PROCESS.*[2] Since the specific gravity of the suspended solids is reduced by the attached air bubbles, the solids/bubble combination will float to the surface of the water. Coagulants may be added to this volume. The coagulant causes a larger floc of solids, trapping the bubble inside. This can improve or increase the effectiveness of each single air bubble. After the solids within the volume form flocs, these flocs rise to the surface. The volume under this sludge mat is clear treated water, which is either re-used in manufacturing or passed on to another stage of water treatment. The recovered solids on the surface of this volume are removed, and also re-used in manufacturing or passed on to another system for sludge handling and dewatering.

6.101 Purpose of the Flotation Process

The flotation process may be used for three basic reasons:

1. Solids Recovery. In some manufacturing processes, valuable solids are discharged from various sources. By installing a flotation unit, these valuable solids can be recovered and re-used in the manufacturing process at a fairly low cost. This is a typical procedure in the pulp and paper industry, the textile industry, the mining industry, and some chemical industries.
2. Water Recovery. Since all indications in industry point to future minimum use and discharge of water in manufacturing locations, the re-use of water is very critical. One way to re-use industrial wastewater with suspended solids as pollutants is to first pass this volume through a flotation unit. Current industry figures reveal that over 94 percent of the suspended solids are removed by many of these units. Because of this high removal efficiency, the clarified water can be re-used in locations throughout the plant where the remaining six percent of the suspended solids will not produce plugging or other problems.
3. Wastewater Treatment. The flotation unit is used extensively in primary industrial wastewater treatment. This is due mainly to the unit's high performance levels, simplicity of operation, and low operating costs.

In all three uses of the flotation process, continuous high levels of performance are necessary to maintain system balance, related systems' balance, and/or compliance of NPDES discharge permit limits.

6.102 Part Identification

Along with understanding the impact of the flotation system as a whole on system balance, permit requirements, and solids recovery, it is just as important to understand the effects of each major part on the flotation system.

Referring to Figures 6.2, 6.3, 6.4, and 6.5, the following parts are of critical importance to the successful operations of the flotation unit:

1. Unit Feed Pump
2. Check Valves
3. Float Valves
4. Air Induction System
5. Chemical Induction System
6. Retention Tank
7. Inlet Header
8. Flight Scrapers
9. Lamell Panels
10. Weirs
11. Motors/Pumps
12. Flow-Measuring Equipment
13. Sampling Equipment
14. Control Valve
15. Flotation Compartment

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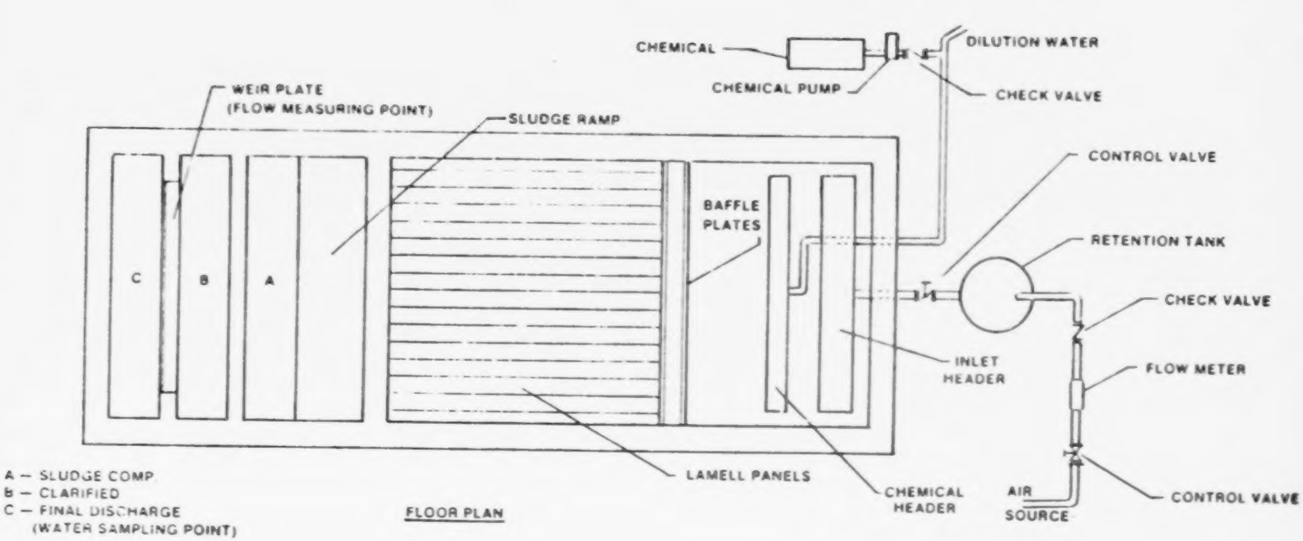
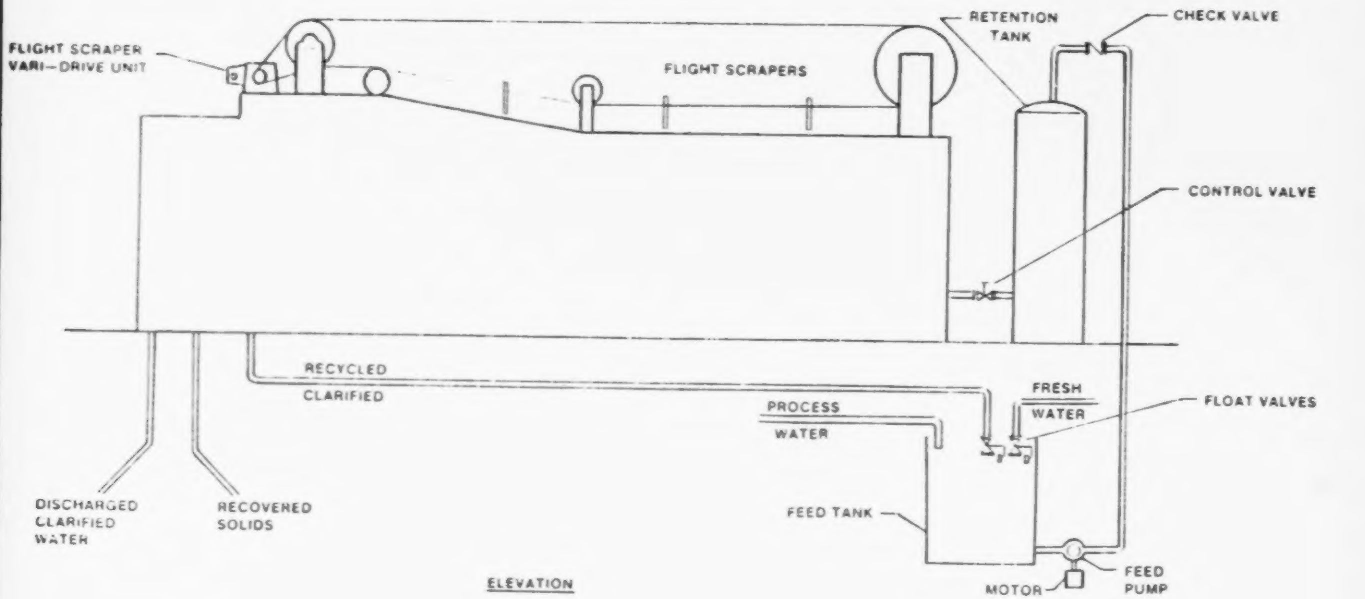
[1] *psig. Pounds per Square Inch Gage. Gage pressure means the pressure above atmospheric pressure. Absolute pressure is the gage pressure plus the atmospheric pressure.*
Absolute Pressure, psia = Gage Pressure, psig + Atmospheric Pressure, psi

[2] *Continuous Process. A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.*

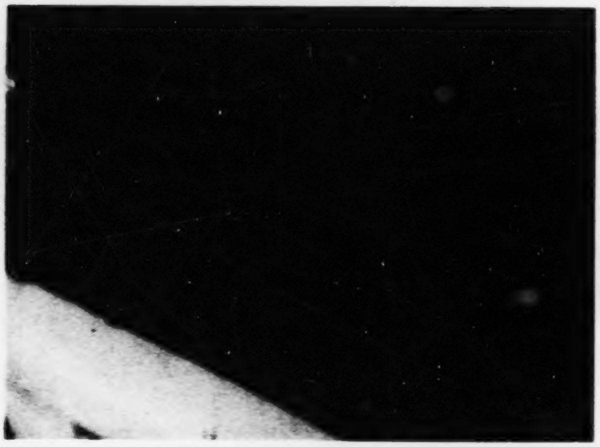

CHEMICAL
DILUTION WATER
CHEMICAL PUMP
CHECK VALVE
WEIR PLATE
(FLOW MEASURING POINT)
SLUDGE RAMP
CONTROL VALVE
BAFFLE
PLATES
RETENTION TANK
C
B
A
CHECK VALVE
INLET
HEADER
FLOW METER
LAMELL PANELS
CHEMICAL
HEADER
AIR
SOURCE
CONTROL VALVE
A — SLUDGE COMP.
B — CLARIFIED
C — FINAL DISCHARGE
(WATER SAMPLING POINT)

FLOOR PLAN

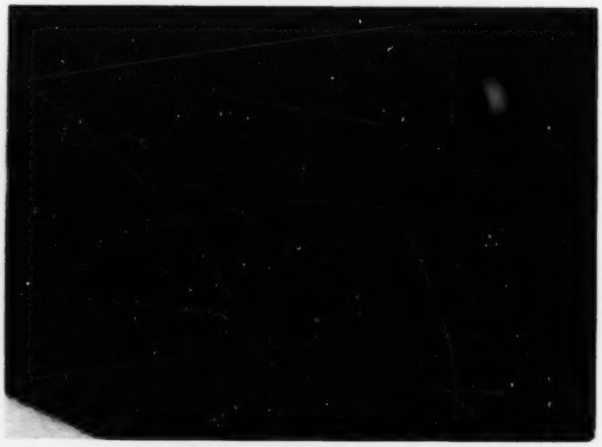

RETENTION
TANK
CHECK VALVE
FLIGHT SCRAPER
VARI—DRIVE UNIT
FLIGHT SCRAPERS
CONTROL VALVE
RECYCLED
CLARIFIED
FRESH
WATER
PROCESS
WATER
FLOAT VALVES
DISCHARGED
CLARIFIED
WATER
RECOVERED
SOLIDS
FEED TANK
MOTOR
FEED
PUMP

ELEVATION

Fig. 6.2 Flotation unit parts
(NOTE: Circular tanks are commonly used also)



Recovered solids being removed from the surface of the water and discharged into the recovered solids compartment by the flight scrapers.

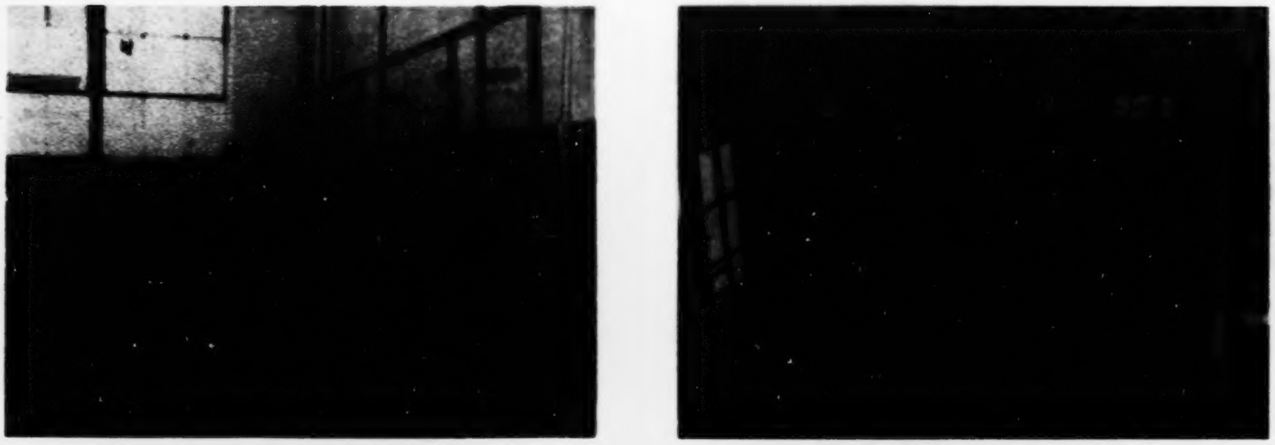


The final discharge weir/clarifier water compartment.

The control valve between the unit and its retention tank. This also shows the manhole in the retention tank.

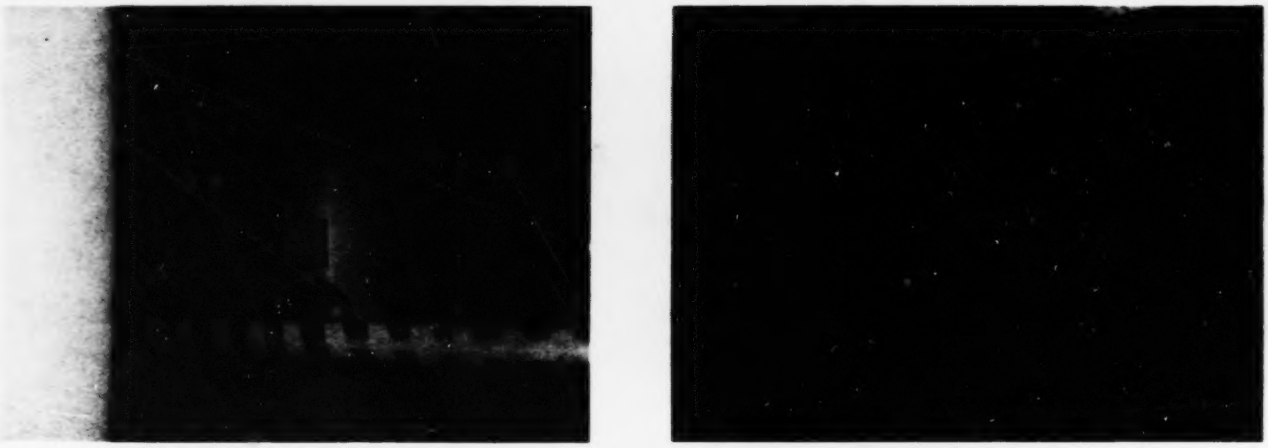
Sprocket/hand rails/nip guard areas of unit.

Fig. 6.3 Photos of flotation unit parts



Chemical pumping system.

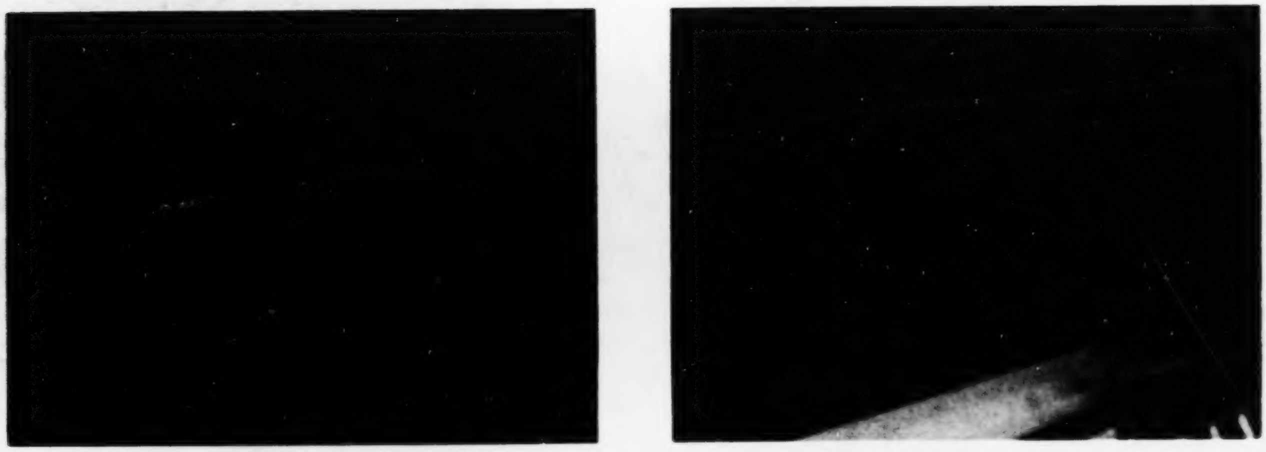
Flight scraper assembly which removes solids.



Retention tank. Also shows hand rail, mid rail, and toe boards on catwalk structure.

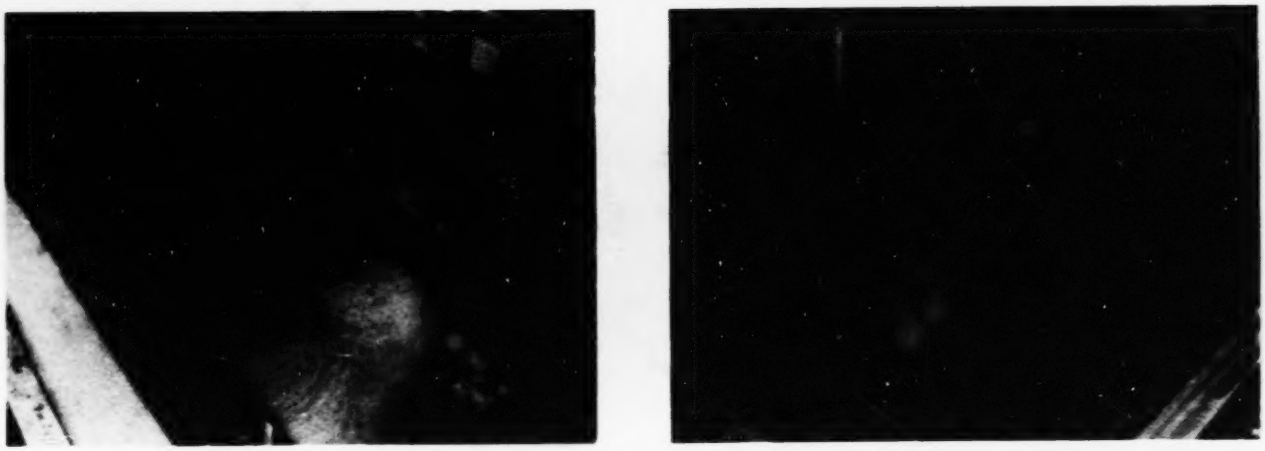
Scraper drive unit and associated guards.

Fig. 6.4 Photos of flotation unit parts



Lamell panels in flotation compartment.

Chemical and stock inlet headers with baffles located in flotation compartment.



System imbalance — too much air.

Sludge ramp, oiler and sprockets.

Fig. 6.5 Photos of flotation unit parts

The failure or misuse of any of these parts can cause a decrease in performance of the system or total system shutdown, neither of which should happen in a well operated plant.

6.103 Part Description

As stated before, the operator must be able to identify each part of the flotation system in order to operate the systems correctly and to pinpoint possible malfunctions. Along with identifying each part, their importance and function must also be known.

Referring to Figure 6.2, the following paragraphs describe the functions and importance of each part.

1. Unit Feed Pump. This is the pump that feeds the flotation system with the solution that is to be treated. Improper operation, worn impellers, blockages, or improper sizing will affect delivered volume which is very critical in the operation of the system.
2. In-Line Check Valves. There are three check valves in the systems. One is in the line between the feed pump and the retention tank. This prevents siphoning back of the solution and possible pump damage on system shutdown. Another check valve is located on the air system line before it enters the retention tank. This prevents the solution in the retention tank from backing up in the air line. The third check valve is on the chemical line before the introduction of the dilution water. This prevents the dilution water from traveling back into the chemical pump.
3. Float Valve. There are two float valves located above the feed tank. One is for the addition of fresh water if necessary. The second float valve regulates the recycle flow from the clarified compartment of the unit to the feed tank. This flow is necessary to maintain the required flow through the feed pump and pressurized air unit during variations in the supply flow to the feed tank.
4. Air Induction System. This consists of a needle valve, flow-meter, and strainer/cleaner. This is the supply system for the air that is necessary for the unit's operation, as explained in Section 6.100.
5. Chemical Induction System. This consists of a chemical pump, check valves, dilution water, and some sort of distribution system within the flotation unit. Without this system, the performance of the flotation system will decrease to about 10 to 20 percent solids removal.
6. Retention Tank. This is a pressurized vessel where the mixing of the treated solution and air takes place. Without this tank, the flotation system would not operate.
7. Inlet Header. This is a device that distributes the flow from the retention tank evenly across the floor of the flotation unit. Partial plugging of this unit causes uneven flow/solids distribution within the flotation unit.
8. Flight Scrapers. These scrapers remove all of the suspended solids that have surfaced from the solution because of the air/chemical/solids reactions. Failure of these units causes buildup of solids from the surface down to the flow of the unit, plugging off all paths for clarified water and rising solids in the solution.
9. Lamell Panels. These panels increase the effective area of flow within the flotation compartment allowing more action in a smaller area and causing a smooth transition of the solids from the bottom of the compartment to the surface.
10. Weirs. There are two weirs on this system. The main weir controls the level of liquid in the unit. The second weir is the flow measuring point for discharge readings from the unit.
11. Motors. The motors in this system operate the feed pump, the chemical pump, and the flight scrapers.
12. Flow Measuring Equipment. This is usually a flowmeter/recorder device matched to the final weir that records the rate of flow and total gallons discharged.
13. Sampling Equipment. This is usually an automatic type composite sampler with refrigeration to meet all specifications of the discharge permit.
14. Control Valve. This valve is located between the flotation unit and the retention tank. The valve controls the pressure drop across the tank and inlet, thus achieving the necessary mixing of the air with the solution.
15. Flotation Compartment. A tank similar to a clarifier where the flocs are allowed to float to the surface and be removed by skimmers.

6.104 Safety

Industrial safety is an important segment of any process or operation. Failure to conform with the simple rules and regulations can be hazardous to your health or to your job. More and more importance is being placed on safety by the federal government, by the state government, and also by the insurance carriers for separate industries.

There are many areas of potential safety hazards within the flotation system. The following paragraphs identify the critical points and the equipment necessary to bring a plant into compliance with safety regulations.

1. Couplings. All couplings on the feed pump, the chemical pump, and the scraper drive assembly have to be guarded.
2. Rotating Shafts. All rotating shafts that extend over one-half of their diameter must be guarded.
3. Sprockets. All gears and sprockets on the chain system that carries the flight scrapers must be enclosed with a guard.
4. Nip Points. All nip points on the chain drive must be guarded.
5. V-Belts and Pulleys. The pulley system on the belt drive for the chemical pump has to be guarded.
6. Electrical. All electrical systems must be installed, marked, and operated according to the National Electric Code.
7. Unit Access. Proper catwalks, stairs, rails, midrails, toeboards, and head clearances must be installed where necessary.
8. Wet Floors and Platforms. Since this is a wet process, due caution, markings, and housekeeping are necessary for a safe floor and platform working environment.
9. Chemical Handling. Where stated by the manufacturer, the proper protective equipment must be worn by any person who handles the chemical.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 448 and 449.

6.1A What is the purpose of the coagulants in the dissolved air flotation process?

6.1B Why must an operator be able to properly identify the critical parts of a flotation unit and their functions?

6.1C What factors could adversely affect the performance of a flotation unit feed pump?

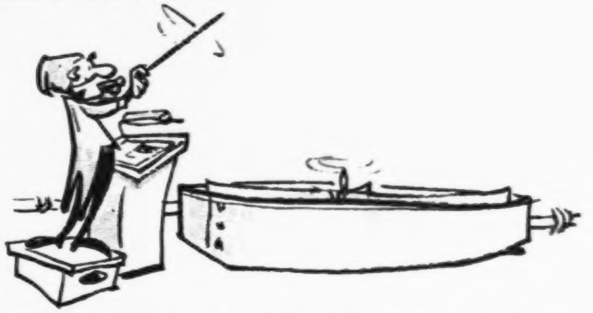
6.1D What is the purpose of the retention tank in the dissolved air flotation system?

6.1E What is the purpose of the flotation tank in the flotation system?

6.11 Systems Operation

6.110 System Start-up Procedures

Systematic start-up procedures are necessary for the efficient operation of the flotation system and will prevent unnecessary wear on system components. Using the correct procedure each time will also point out possible component malfunctions within the system.



The correct sequence for the start-up of this system is listed below:

1. Close all drain lines from all tanks, compartments, and dump valves within the system.
2. Fill the flotation unit with fresh water. This will prevent the feed pump from operating dry which causes unnecessary wear and damage.
3. Open the chemical feed system and dilution water and turn on the chemical pump. This will start the reaction with suspended solids immediately, reducing the volume of discharged suspended solids on initial start-up.
4. Open the control valve to the 50 percent position. This is the logical starting point during start-up before actual adjustment takes place.
5. Crack open the air induction system. This will also cause immediate reactions to take place to remove solids on initial start-up. Opening the system just a little bit does not put the retention tank in imbalance, but supplies minimum air to do the job until final adjustments are made.
6. Open the feed valve 50 percent. This also is the ideal starting position of the valve until all flows balance out and final adjustments can be made.
7. Start the feed pump.
8. Go back and adjust the air to the retention tank to the desired level.
9. Adjust the feed valve to the position where all flows are balanced.
10. Start the flight scraper drive. Failure to do so now will cause the buildup of sludge to depths within the flotation compartment where shutdown and wash-up procedures will be necessary to clean out the unit.
11. Adjust the flight scraper speed to the desired speed. Too slow a speed will cause heavy buildup of sludge with the possibility of overloading the drive unit and plugging the flotation compartment. Too fast movement of the scrapers causes too much disturbance in the flotation compartment and dilutes the sludge. The ideal setting is where the scrapers keep up with the sludge without disturbing the compartment and deliver the sludge consistency that you are looking for.

6.111 System Shutdown Procedures

As important as proper start-up procedures are on system performance and protecting equipment, the correct procedures must also be followed in shutdown actions on the flotation system.

The proper sequence is as follows:

1. Turn off the air supply.
2. Turn off the chemical supply.
3. Flush out the retention tank by opening and closing the drain valve quickly. This removes all rust particles, dirt and other foreign matter that has settled on the bottom of the retention tank.
4. Turn off the feed pump.
5. Turn off the flight scraper drive.
6. Drain all of the unit's compartments.
7. Pump fresh water through the system by using the fresh water inlet to the feed tank and by starting up the feed pump after all compartments have been drained. This flushes out all of the lines which cannot be cleaned except by complete disassembly. Shut the pump off when inlet flow clears up to the flotation unit.
8. Wash down all the walls, floors, panels, scrapers, and weirs with fresh water from a hose. This will knock off all of the accumulated slime and solids which normally build up during extended use. Failure to wash the inside of the unit will make the performance level after start-up drop below accepted levels.
9. Close all drain valves and dump valves after all surfaces are cleaned.
10. Return all control valves to their normal operation positions when ready for start up.

6.112 Start-up and Shutdown Procedure Evaluation

After the completion of either the start-up procedure or the shutdown procedure, an evaluation must be made to be sure that the proper steps were taken and no steps were omitted.

The proper procedures have been outlined in the two previous sections. Remember, equipment may be damaged by using improper procedures. Failure to fill the unit with fresh water before starting the feed pump can damage the pump. Not closing the drain valves before filling the units would cause a waste of water and time. By not turning on the air, the effluent quality will suffer.

The shutdown procedure is also critical. Leaving the chemical feed on until after all jobs are completed would be a waste of chemicals and money. Opening and closing the drain valve on the retention tank after the feed pump is shut off would be a waste of energy, and so on.

Incorrect procedures or steps taken out of sequence are usually very noticeable either by sound, indicator lights, effluent quality, visual appearances of the unit, or by mechanical malfunctions.

6.113 Wastestream Evaluation

Wastewater evaluation plays an important role in the operation of a flotation system. The evaluations are just not lab findings alone. All the senses play a part in the system evaluation. These evaluations are necessary to maintain the system in balance and to run the system at the lowest cost.

Wastestream evaluations consider the following items:

1. Increase in floating solids. On the clarified water side of the flotation unit, a small amount of floating solids is normal. When a sludge mat starts forming on the surface from too many solids, the system is out of balance.
2. Increase in suspended solids. Lab tests or visual comparisons of clarity of the discharged water will reveal an increase in suspended solids.
3. Variations in the flow to the unit. These will be noticed by variations of the liquid level in the unit or large fluctuations in the volume of discharge flow.
4. Variations in odor. This can be noticed very rapidly when entering the area.
5. Variations in pH. Tests for pH levels must be done either in the field or in the lab.
6. Variation in color or turbidity. Tests can be done in the lab or the operator may observe changes in the discharge flow.
7. Variation in the floc of floating and suspended solids. Changes can be detected by observing the unit's sludge mat or by taking samples and observing floc arrangement.

Wastestream evaluation is very critical to the solving of problems, for the prevention of problems, and as an aid in troubleshooting the flotation system.

6.114 Reaction to Abnormal Indicators

To keep a system in balance, the operator must first recognize the indicators of an abnormal condition and then take appropriate corrective action. There are basically two types of indicators in the flotation process. One type is the non-serious indicator. Going back to the previous section, an increase in floating solids, an increase in suspended solids, variations in pH, variations in color or turbidity, and variations in floc can be considered non-serious. These variations can be minimized or totally corrected by the operator without shutting down the system.

1. Increase in floating solids can be corrected by one or a combination of the following, depending on the condition:
    a. Adjusting scraper speed,
    b. Adjusting air to retention tank,
    c. Adjusting chemical to flotation unit, and
    d. Adjusting control valve to change tank pressure.
2. An increase in suspended solids can be corrected as in an increase of floating solids.
3. Variations in pH can result from uneven flows of fresh water, varying chemical supply from the chemical pump, or from changes in the manufacturing process upstream from the flotation units. The chemical supply can be corrected at the pump. The other two require an investigation to identify the source of the problem and to determine corrective action.
4. Variations in color or turbidity usually can be corrected by adjusting the rate of chemical addition and by adjusting the air supply to the system.
5. Variations in floc can almost always be corrected by finding the ideal chemical addition rate to the system.

The second group of indicators are the serious ones. These are the indicators that mandate the shutdown of the total system to correct the problem. Again referring to the previous section, the variation of flow to the unit and the variation of odor are two indicators of serious imbalances in the system.

1. Variation of flow to the unit could be caused by (a) blockage in the feed pump; or (b) a worn out pump creating surges in flow. In both cases, the pump has to be shut down for inspection and corrective maintenance.
2. Variations in odor usually mean that the normal system wash-up schedule has not been followed. The corrective action needed here is to shut down the system and clean it thoroughly (boiling it out if necessary) to remove the septic/rotten substances from all the surfaces.

All of the abnormal indicators and any corrective actions taken should be recorded in the system's log. Serious indicators and the corrective actions taken should be reported to a supervisor as soon as possible. This is the first step towards reporting to the agencies involved whenever the quality of the discharge stream is affected by a slug or spill of insufficiently treated water.

Whatever the abnormal indicators are or whenever they take place, immediate corrective action is required to minimize adverse effects on effluent quality.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 449.

6.1F What can go wrong if the flight scraper drive is not started at the proper time?

6.1G What happens when the flight scrapers travel too slowly?

6.1H What happens when the flight scrapers travel too fast?

6.1I Why is the retention tank and flotation unit flushed out and washed down during the shutdown procedures?

6.1J List the possible improper start-up and shut-down procedures and a possible result or consequence of each improper step.

6.1K Why is wastestream evaluation important?

6.1L List two serious indicators that mandate the shutdown of the flotation unit and give the possible cause of each indicator.

6.115 Recording of Data

Accurate recording of system data is very important for system evaluation and, in some cases, is required under the firm's or plant's discharge permit. General trends can be noticed from these reports. For example, performance can be compared to separate stream characteristics such as gradual system slime buildup leading to wash-up operations; seasonal variations may be noticed; or results of overloadings or slugs on the system can be seen. This overview is needed to operate the system, to plan other new systems, and to provide for discharge permit modifications. Also, the data can pinpoint another possible trouble area: an operator needing additional training.

The basic items that should be included in this "operation log book" are as follows:

1. Date
2. Time
3. Operator's name
4. Upstream conditions within the plant
5. Flow to unit
6. Flow from unit
7. Chemical consumption
8. Total suspended solids (TSS) to unit
9. TSS from unit
10. Percent TSS removal
11. Other information required by the company or industry and state and federal agencies
12. General operating data
    a. Breakdowns
    b. Spare parts used
    c. Abnormal indicators noticed
    d. Corrective actions
13. Air flow
14. Air pressure

If accurate records are maintained on a daily basis, the performance of the units, the cost of operation, and the quality of the discharged flow will improve and remain constant.

6.116 Sampling

There are two types of routine sampling. One type is the routine sampling schedule set up in your discharge permit for compliance. The second type of sampling is for your operation log book. Both are important for the reasons explained in the two previous sections.

There are two sample points in the flotation system. The first is before the system, and the second is after. The difference between the two is the performance level. The first sample point can also give the system operator data on variations in loading upstream from the unit.

Samples can be taken either as grab or composite. Grab samples will give you results of slug loadings, dumps, or accidental spills by themselves instead of mixed with normal variations. The composite sample is the average loadings over a specified period of time. This type of sampling of solids, BOD, and COD levels is required by all discharge permits. Grab samples for temperature, slugs, spills, and dumps are usually accepted.

If economic conditions at your firm or plant permit, the easiest and best method of sampling is to use an automatic sampler with refrigerator. This device can be set up to sample at various time periods and volumes. The refrigeration will preserve normal samples until the next day for analysis. pH, temperature, and flow can also be monitored by continuous recording equipment, or can be done manually, whichever is required by your permit.

In summary, routine sampling and analysis are required when operating a flotation system for permit compliance and for operating the units properly.

6.117 Routine Calculations

To operate a flotation system economically and within discharge permit limits, the operator must be prepared to perform several routine calculations when gathering and using data about the system.

The majority of flotation units have standard contracted rectangular weirs in the final position where flow is measured. The influent and effluent flows of the unit can be calculated from this weir.

The influent flow is the flow over the discharge weir at 0 percent recycle back to the feed tank. The discharge flow is the flow over the discharge weir at anytime with from 0 percent recycle to 100 percent recycle. In some installations there is no recycle flow.

The formula for calculating the flow over this weir is as follows (Francis Formula):

$$Q = 3.33\ LH^{3/2} \qquad (1)$$

where

Q = the discharge or flow in cubic feet per second (cfs), (the approach velocity is neglected)

L = the length of the weir in feet, and

H = the head on the weir in feet.

The flow can also be calculated by the formula:

$$Q' = 3.3L\ (H + h)^{3/2} - h^{3/2}, \qquad (2)$$

where

Q′ = the discharge or flow in cubic feet per second (cfs), (the approach velocity is considered)

L = the length of the weir in feet,

H = the head on the weir in feet, and

h = the head in feet due to the approach velocity ($h = V^2/2g$ and $g = 32.2\ \text{ft/sec}^2$)

If the cross-sectional area of the channel or flume just upstream from the weir is less than five times the area of flow over the weir, the approach velocity will increase the discharge a noticeable amount. In this situation, use equation (2) to consider the approach velocity ($h = V^2/2g$).

EXAMPLE

Calculate the flow in cubic feet per second (cfs) over a standard contracted rectangular weir if the weir length is 30 inches and the head on the weir is 6 inches.

Known	Unknown
Contracted Rectangular Weir	Flow, cfs

$$\text{L, ft} = \frac{30\ \text{in}}{12\ \text{in/ft}} = 2.5\ \text{ft}$$

$$\text{H, ft} = \frac{6\ \text{in}}{12\ \text{in/ft}} = 0.5\ \text{ft}$$

Calculate the flow in cfs over the weir.

$$\begin{aligned}\text{Flow, cfs} &= 3.33 \times (\text{L, ft}) \times (\text{H, ft})^{3/2}\\ &= 3.33 \times 2.5\ \text{ft} \times (0.5\ \text{ft})^{3/2}\\ &= 3.33 \times 2.5 \times 0.35\\ &= 2.94\ \text{cfs}\end{aligned}$$

The suspended solids loading on the flotation unit can be calculated as follows:

$$\text{Suspended Solids Loading, } \frac{\text{lbs}}{\text{day}} = \text{Flow, MGD} \times \text{TSS, mg/}L \times 8.34\ \text{lbs/gal} \qquad (3)$$

The BOD loading on the flotation unit can be calculated as follows:

$$\text{BOD Loading lbs/day} = \text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\ \text{lbs/gal} \qquad (4)$$

To calculate the percent removal of either suspended solids or BOD, use the following formula:

$$\text{Removal, \%} = \frac{(\text{Influent, lbs/day} - \text{Effluent, lbs/day})}{\text{Influent, lbs/day}} \times 100\% \qquad (5)$$

EXAMPLE

Determine the suspended solids and BOD loadings on a flotation unit if the flow is 2 MGD and the influent suspended solids are 1,500 mg/*L* with a BOD of 75 mg/*L*. What is the percent removal of suspended solids if the effluent flow is 2 MGD and the suspended solids are 100 mg/*L*?

Known	Unknown
Flow, MGD = 2 MGD	1. SS Loading, lbs/day
Infl. SS, mg/*L* = 1,500 mg/*L*	2. BOD Loading, lbs/day
Effl. SS, mg/*L* = 100 mg/*L*	3. SS Removal, %
Infl. BOD, mg/*L* = 75 mg/*L*	

1. Calculate the influent suspended solids loading in pounds per day.

$$\begin{aligned}\text{SS Loading, lbs/day} &= \text{Flow, MGD} \times \text{Infl. SS, mg/}L \times 8.34\ \text{lbs/gal}\\ &= 2\ \text{MGD} \times 1500\ \text{mg/}L \times 8.34\ \text{lbs/gal}\\ &= 25{,}000\ \text{lbs suspended solids/day}\end{aligned}$$

2. Calculate the influent BOD loading in pounds per day.

$$\begin{aligned}\text{BOD Loading, lbs/day} &= \text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\ \text{lbs/gal}\\ &= 2\ \text{MGD} \times 75\ \text{mg/}L \times 8.34\ \text{lbs/gal}\\ &= 1{,}250\ \text{lbs BOD/day}\end{aligned}$$

3. Determine the percent suspended solids removal.

   a. Calculate the effluent suspended solids in pounds per day.

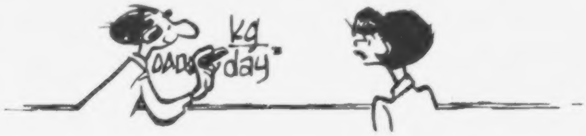
$$\begin{aligned}\text{Effl. SS, lbs/day} &= \text{Flow, MGD} \times \text{Effl. SS, mg/}L \times 8.34\ \text{lbs/gal}\\ &= 2\ \text{MGD} \times 100\ \text{mg/}L \times 8.34\ \text{lbs/gal}\\ &= 1{,}668\ \text{lbs SS/day}\end{aligned}$$

   b. Calculate the percent suspended solids removal.

$$\begin{aligned}\text{SS Removal, \%} &= \frac{(\text{Infl, lbs SS/day} - \text{Effl, lbs SS/day}) \times 100\%}{\text{Infl, lbs SS/day}}\\ &= \frac{(25{,}000\ \text{lbs/day} - 1{,}668\ \text{lbs/day}) \times 100\%}{25{,}000\ \text{lbs/day}}\\ &= 93.3\%\end{aligned}$$

To calculate the loadings in the metric system, use the following formula:

$$\text{Loading, } \frac{\text{kg}}{\text{day}} = \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \text{SS,} \frac{\text{mg}}{L} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}} \times \frac{1{,}000\ L}{1\ \text{cu m}}$$



6.118 *Effect of Operator Actions and Reactions*

As pointed out in previous sections, one problem might have a number of different solutions. What has to be done by the operator is to correct the problem systematically, not by just random adjustments on a number of different components or parts.

There are some basic rules to follow when correcting problems. They are as listed below:

1. Assess the problem;
2. List possible corrective actions;
3. Proceed to correct the problem by doing one corrective action (or change one variable) at a time;
4. Record all actions;
5. Evaluate system response to each action; and
6. After problem is corrected, try to prevent it from developing again.

The operator must not change more than one variable at a time. Because of the fact that there are numerous solutions to one problem, a systematic approach has to be taken. This will decrease the time period of system imbalance and increase the knowledge of the operator about how to correct various problems, especially if records are kept.

Also, give each change a chance to affect the unit. If you change variables without waiting to see the reaction, it is the same as changing numerous variables at the same time.

Along with systematically changing variables and waiting for the reactions, the amount of change is also important. Drastic changes in component or part settings creates other problems in system operation. Some results of over reactions are:

1. Rapid change in retention tank pressures. This causes variations in the solution/air relationship and can cause system flow problems.
2. Rapid change in flight scraper speed. Too slow a speed tends to increase the consistency of the sludge mat. This will cause the mat to increase in size downward, thus plugging the flotation compartment. This could also cause failure of the flight scraper assembly because of increased weight due to the consistency change. Too fast a speed will disturb the floating action of the solids, causing the performance of the unit to drop. These two changes in sludge consistency also affect the point of reuse of the recovered solids.
3. Variations in the chemical flow. This could change the performance of the unit and adversely affect the discharge flow quality. Over-supplying chemicals will cause a buildup of chemical in the system which could affect the manufacturing process wherever the clarified water or sludge is used. In addition, over-use of chemicals is very costly.
4. Extreme changes in total flow into the unit. This generally upsets the loading balance to the unit, thus decreasing the efficiency of the system to the point of non-compliance with set standards or permit requirements.
5. Extreme changes in air flow to retention tank. This has the same end effect as changes in total flow, almost complete failure of the system to treat the waste flow.

The operator must know the proper corrective actions and perform these actions on a systematic basis. Each change has to be monitored until reactions take place before the operator makes further adjustments. Each change has to be a gradual change, not one of large magnitude that will upset the system. Also, if the operator maintains an operation log book, a repeat of a similar problem in the future could be assessed on past experiences, thus cutting down the time of system imbalance.

6.119 Frequency of System Monitoring

The frequency of system monitoring can mean the difference between compliance and non-compliance with discharge limits, or the loss of water and solids recovery which is the purpose of the system.

Reporting schedules to the required government agencies vary with each location or state. The best system of monitoring requires personnel on each shift to monitor themselves. Under this monitoring program, continuous system operational levels are monitored, pointing out problem areas and abnormal indicators as soon as they develop. Checking the system this frequently will also keep any or all chemical costs at the minimum. The information gathered by this testing can be used for system evaluation, discharge permit calculations, or operator evaluation.

The frequency of monitoring will increase when abnormal indicators are present. Continuous monitoring is required under this condition until system evaluations point out that all problems have been corrected.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 449.

6.1M Why is a daily operation log necessary?

6.1N What information can be obtained from analysis of the accumulated log data?

6.1O Results from sampling are recorded for what two purposes?

6.1P List the basic rules to follow when correcting a problem.

6.1Q How long should you wait between changes when attempting to correct a problem?

6.1R When is continuous monitoring required?

6.12 Preventive Maintenance

6.120 Pertinent Procedures

The operator of a flotation unit must know appropriate procedures in preventive maintenance to maintain the system in the proper mechanical operating condition. Preventive maintenance, that maintenance which is performed on equipment to keep it from malfunctioning, is very important to effective system operation.

The pertinent procedures in preventive maintenance are as follows:

1. Facilities Painting. All metal surfaces should be painted where necessary to prevent deterioration from rust and/or chemical reactions.

2. System Cleaning. Flowmeters, check valves, control valves, and inlet headers should be cleaned on a scheduled basis to minimize plugging or failure which affects performance of the unit.
3. Adjustment of Chains and Scraper Alignment. This will increase the life of all parts of the flight scraper system.
4. Belt Wear. All V and flat belts should be checked for wear so as to prevent failure of a part because of a broken or slipping belt.
5. Grease and Oil. All components which need grease and oil should be maintained in accordance with the manufacturer's specifications.

Preventive maintenance is extremely important to maintain the flotation system in proper working order and to minimize system down-time and serious equipment problems.

6.121 Procedures and Their Frequencies

The frequency of preventive maintenance is very important. Procedures done too often are a waste of time and energy, and could possibly damage a part. If procedures are done at irregular time intervals or not at all, part failure or other problems could develop. Based on the procedures listed in the previous section, the recommended frequency of preventive maintenance is as follows:

1. Painting. All painting should be done when necessary to maintain appearance and to prevent surface deterioration.
2. Cleaning of the Unit and Parts. Broken down into separate units:
   a. Outside Unit. Clean once per month.
   b. Inside Unit. Clean twice per month.
   c. Stock Header. Clean twice per month.
   d. Chemical System. Clean once per month.
   e. Retention Tank. Clean twice per month.
   f. Check Valves. Clean once per month.
   g. Control Valves. Clean once per month.
   h. Feed Tank. Clean once per month.
   i. Room. Clean when necessary.
3. Adjustment of Chains and Scrapers.
   a. Chain. Adjust once per month.
   b. Scrapers. Adjust once per month.
4. Belt Wear. Check once per month.
5. Grease and Oil. Check and refill as necessary once per month or as per manufacturer's specifications.
6. Feed Pump. Check wear on internal parts four times per year.
7. Valves. Check operation twice per month.

If the above schedule of preventive maintenance is followed, system down-time, mechanical failures, and performance drops because of separate part failures can be minimized.

6.122 Required Actions by the Operator

The operator of the flotation unit has to know how as well as when to perform preventive maintenance. A fixed sequence of maintenance procedures will help the operator. Complete the job correctly and as quickly and safely as possible with minimal system interference. If maintenance must interrupt the system's operation, the use of proper procedures is even more essential.

Under normal conditions the following steps are necessary to perform preventive maintenance correctly:

1. Identify the necessary maintenance step. Time is wasted and possible harmful effects on system balance occur if the wrong job is done on the equipment.
2. Pick out the proper tools and equipment. This will save time during the procedure by revealing any missing equipment that is necessary to perform the maintenance. Collect the tools you'll need before starting the job, not while you are trying to do the job.
3. Review the effects of the maintenance on the immediate operation of the system. If the required preventive maintenance does not affect the immediate operation of the unit, proceed with the job. If the procedure does affect the operation, go to the next step.
4. Contact your supervisor if a procedure will affect the operation of the system. Do this before actual maintenance. Follow your supervisor's orders. The supervisor must know in advance when maintenance procedures will affect water, solids, or discharge qualities so appropriate steps can be taken to compensate for any upset.
5. Perform the work. The work should be done as quickly and safety as possible so no harm comes to the employees or to the equipment.
6. Replace all guards and reset parts. These two items are of critical importance. The correct settings are critical so that the operator knows where the system is operating. The replacement of guards is required so nobody will take for granted that the guards are in place, when they are not, and possibly get seriously injured.
7. Clean up. This is necessary for general good housekeeping. While cleaning up, try to locate or account for any tools you have used. Replacement of lost tools increases maintenance costs.

6.123 Importance of Preventive Maintenance

As stated in previous lessons, preventive maintenance is very important for the proper operation of the flotation system. To be more specific, maintenance affects four areas of operation:

1. Effect on system operation. The preventive maintenance schedule will reduce system down-time compared to just corrective maintenance. Bearings, motors, pumps and chains have to be oiled or greased in order to prolong part life. Belts have to be checked for the same reason. If the preventive maintenance schedule is not followed, separate part failures will occur at an abnormally high rate. Smooth and proper system operation cannot be maintained without preventive maintenance.
2. Effect on system performance. All preventive maintenance points affect system performance. For example, if the unit is dirty, performance goes down; if the chemical system is partially plugged, the solids will not floc to desired levels; if the air system check valve is plugged, air will not get into the retention tank to perform its necessary duties; and so on.
3. Effect on department budget. All unnecessary unit down-time because of lack of preventive maintenance is costly.

Parts are expensive. Part failures due to poor maintenance create extra labor and repair costs that could have been avoided. The whole idea of preventive maintenance is to ensure smooth system performance at the lowest cost.

4. Effect on waste stream. Depending on the purpose of the flotation system, the final product will be affected. With proper preventive maintenance procedures, the system will operate mechanically at the desired levels, maintain required levels of treatment, and give end results of compliance with the system's requirements.

6.124 Determination of Preventive Maintenance

In addition to your regularly scheduled maintenance tasks, be alert for the following conditions which also require prompt attention:

1. Signs of wear. Worn belts on pulleys and worn sprockets on the flight scraper require adjustment of the pulleys and chains to reduce wear. Low inlet pressure may indicate a worn pump in need of repair.
2. Lack of oil. This will be very noticeable by visual inspection of the dip stick or sight gage.
3. Abnormal noises. After the operator has had experience operating the system, the operator will be able to pick up abnormal sounds and possibly identify which part is in need of maintenance. This is just as important as visual inspection and the time schedule for preventive maintenance.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 449.

6.1S What is preventive maintenance?

6.1T What are the results of too frequent or irregularly spaced preventive maintenance procedures?

6.1U Why should all guards be replaced and part settings be returned to the original settings after maintenance is performed?

6.1V List the four major areas of plant operation that are influenced by preventive maintenance.

6.13 Corrective Maintenance

6.130 Evaluation for Corrective Maintenance

Corrective maintenance is also important for the proper operation of a flotation system. However, the operator must evaluate the seriousness of each problem to justify corrective maintenance since total shutdown of the system is usually required to repair or replace malfunctioning parts.

All of the previous sections in this lesson explain normal and abnormal conditions of the system including noise, odor, part failure and visual appearances. Before the system is shut down for corrective actions, make sure that the problem cannot be solved by part adjustments. Consider the possibility that variations upstream of the system have changed causing the appearance of part malfunctions. A change such as heavy solids loadings may decrease unit performance and look like chemical or air system failure if not checked out. Review all possible causes of the problem before concluding that corrective maintenance is necessary. You could cause even more serious problems by correcting something that doesn't need to be corrected.

6.131 Causes of Component or Part Malfunction

The evaluation and correction of equipment malfunctions by the use of corrective maintenance is necessary. What is just as important as correcting the problem is understanding why the part failed so that repeated part failure is eliminated as much as possible.

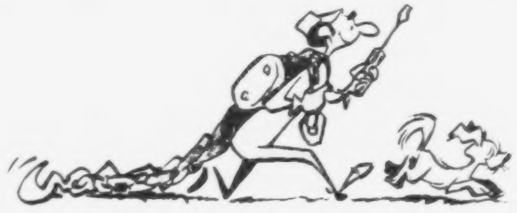
There are six general areas of component or part failure that must be evaluated after every malfunction.

1. Lack of proper preventive maintenance. This will be noticeable from the lack of oil or grease, continuous uneven part wear, or lack of cleaning.
2. Improper installation. This will be noticeable by force marks on metal surfaces, possible lack of small parts, or parts that are installed backwards.
3. Product defects. Poor quality bearings, valves that do not close or seat correctly, or check valves that do not work freely are defective products that should not be installed.
4. Improper operation. At times, there is a temptation to apply force to certain parts to make them operate. Wrench marks on surfaces, bent linkages, or removal of certain component parts in order to over-ride component operation are indications that force has been applied.
5. Old age. Parts that simply wear out by use are responsible for the majority of problems requiring corrective maintenance. With time and normal use, belts dry out and crack and bearings and linkages wear down. Timely replacement of worn parts contributes to efficient operation.
6. Overloading. This could be seen in the failure of flight scraper panels due to overloading of solids to the unit, or in repeated electrical kick-outs caused by trying to pump more volume than the system can handle (excessive amps).

Each incident requiring corrective maintenance must be researched to determine the cause of failure in order to operate the system effectively and reduce unnecessary costs. Repeated down-time for the same corrective maintenance job is not acceptable. Corrective maintenance means resolving the existing problem as well as preventing its recurrence.

6.132 Required Equipment to Perform Corrective Maintenance

The operator has to have the proper tools, testing equipment and spare parts inventory to operate the flotation process as smoothly as possible.



The tools that are required to perform corrective maintenance are basically those found in a well-equipped maintenance shop — from screwdrivers to chain hoists. Experience will dictate the proper tools for a specific installation. Electrical testing equipment is necessary to monitor and troubleshoot system problems.

Other than tools, the most important maintenance resource is a spare parts inventory. Without the inventory, unnecessary down-time of the system will be adding up and will drastically affect the discharge stream or solids and water recovery. There is no excuse for this type of down-time.

6.133 Corrective Maintenance Procedures

As in preventive maintenance, the proper steps have to be taken in corrective maintenance so the job can be done as quickly and safely as possible to avoid harming the waste stream or plant personnel.

The steps are as follows:

1. Identify the problem. Review the six general causes of part failure listed in the previous section. Normal checks may reveal hot bearings or a system that is not clean, for example.
2. Line up the necessary tools and parts. This will save time and will identify a lack of tools or parts necessary to perform the maintenance.
3. Evaluate the problem to see if your personnel can correct the malfunction or if the part has to be shipped out or help from the outside has to be sent in. This is necessary before actual tear-down begins. Time and money will be saved by avoiding unnecessary tear-downs when outside help could fix it on the spot.
4. Again, notify the supervisor of all conditions before total shutdown or directly after if emergency conditions cause automatic shutdown.
5. Put into effect all company emergency plans if the unit is to be inoperable for an extended period of time or if discharge stream quality is to be affected above discharge limits.
6. Perform the work as quickly and safely as possible.
7. Replace all guards and component settings for the same reasons as listed for preventive maintenance procedures.
8. Clean up after the job is completed.
9. Record all information in the operation log book for future references. This will minimize the recurrence of separate problems and make other maintenance jobs run more quickly and smoothly.
10. Reorder all parts used. This is necessary to maintain the proper spare parts inventory.

6.134 Importance of Efficient and Quick Corrective Maintenance

In summary of this section, the corrective maintenance program has to take place as quickly and safely as possible without affecting the quality of the job.

By missing steps required in corrective maintenance, or by not maintaining adequate tools, spare parts, or the proper records, unnecessary system down-time will prevail. This will, in its worst form, seriously affect the quality of the discharge flow from the system. If the discharge flow goes directly from these units to the receiving stream, noncompliance of permit limits and its consequences will take place. If the discharge goes to other stages of treatment, the ineffectiveness due to improper maintenance will jeopardize the operations of all systems downstream.

Systematic corrective maintenance is a requirement of proper system operation. Getting the job done as quickly as possible can prevent the development of adverse conditions resulting from prolonged system shutdown.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 449 and 450.

6.1W What does corrective maintenance require?

6.1X List several causes of part malfunctions.

6.1Y Why is a spare parts inventory necessary?

6.1Z Why is quick and efficient corrective maintenance required?

END OF LESSON 2 OF 6 LESSONS ON INDUSTRIAL WASTE TREATMENT

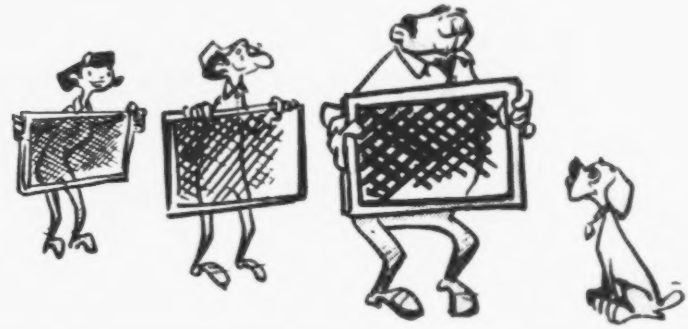
Please answer the discussion and review questions before continuing with Lesson 3.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 6 Lessons)

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 1.

7. How does the dissolved air flotation process work?
8. Why are both solids recovery and water recovery important in the flotation process?
9. Why must proper start-up procedures be followed when starting a flotation unit?
10. Why is it important to make one change in component or part settings at a time when trying to correct operational problems?
11. Why is preventive maintenance important?
12. Why and under what conditions should you inform your supervisor of future preventive maintenance?
13. In evaluating the need for corrective maintenance, what steps should be taken before shutting down the system?



CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

(Lesson 3 of 6 Lessons)

6.2 SCREENING AND MICROSCREENING APPLIED TO INDUSTRIAL WASTE TREATMENT by Tony Diaper

6.20 Need for Screening and Microscreening

SCREENS[3] and *MICROSCREENS*[4] are used in industrial waste treatment to intercept and remove suspended solids from the flowing wastewater. There are three grades of screens which can be used. Coarse screens are used for primary treatment, microscreens (fine screens) are used for final polishing and there is an intermediate grade of medium screening, a relatively recent development, which can be used in conjunction with, or in place of, a primary clarifier.

Removal of suspended solids by these screens before other treatment processes allows the downstream processes to function more effectively. Screening also provides a convenient way of collecting and disposing of particulate matter because the solids are often removed from the screens in a semi-dry condition.

Screens take up less space than clarifiers and are not so much affected in performance by changes in flow rate or temperature. However, if it is more convenient to deal with the solids removed from the wastewater in the form of a sludge, then pumping sludge from a clarifier for subsequent treatment or dewatering may be preferred over a screen. In many cases, the method of wastewater solids separation (screens or clarifiers) depends on the method of sludge handling and disposal at a particular plant.

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[3] *Screen. A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.*

[4] *Microscreen. A device with a fabric straining media with openings usually between 2 and 60 microns. The fabric is wrapped around the outside of a rotating drum. Wastewater enters the open end of the drum and flows out through the rotating screen cloth. At the highest point of the drum, the collected solids are backwashed by high-pressure water jets into a trough located within the drum.*

Microscreens are used for final treatment or "polishing" to prevent the carryover of floating solids and suspended particles in the effluent following other purification processes. They safeguard against deterioration in performance of the upstream processes, although there is a limit to the deterioration which can be treated by the microscreen before overloading and bypassing occurs.

Coarse screens are often placed downstream of grit removal processes in order to protect the screening equipment. On the other hand, coarse screens are used upstream of grit removal in some plants to eliminate floating material before the grit chamber or channel. However, in industrial waste treatment, grit usually is not a problem and special provisions for grit removal are unusual.

Medium screens are used in conjunction with, or in place of, primary sedimentation tanks. They reduce the organic load on aeration processes or trickling filters by removing most of the large particles in suspension. This allows the biological process to function more efficiently. Solids dewatering is assisted by screening because the solids are often removed in a semi-dry condition.

In some cases, medium screens are used as part of the solids dewatering process. For example, the underflow from a clarifier would be pumped as a slurry to the screening process to assist in removing some of the water in the sludge.

Since microscreens are used for final polishing, the only in-plant process directly affected is disinfection, if disinfection is being used. Chlorine is commonly used for disinfection.The use of microscreens will allow smaller doses of chlorine and also could give more complete disinfection due to the removal of floatable and suspended solids.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 450.

6.2A What is the purpose of screens and microscreens in industrial waste treatment?

6.2B How could microscreens be an aid to disinfection?

6.21 Description of Screens

6.210 Stationary Screens

Bar screens (Fig. 28.6) consist of vertical or inclined steel bars spaced at intervals across the channel through which the wastewater flows. They are used ahead of other treatment processes to eliminate coarse objects which could cause damage or defects in operation. Bar screens usually have relatively large openings, between one and four inches (2.5 to 10 cm), and their principal function is to prevent heavy floating objects from entering the treatment plant. They may be cleaned manually or by mechanical rakes. Mechanical cleaning devices consist of rakes that periodically sweep the screens and remove the solids for disposal (Fig. 28.6). Most bar screens use endless chains or cables to move the rake teeth through the screen openings. The screens may be front or back cleaned.

The following types of controls can be used alone or in combination to clean screens:

1. Manual start/stop,
2. Automatic start/stop by time control,
3. High level switch, and
4. Differential head switch.

Mechanically cleaned bar screen mechanisms will discharge on the upstream or downstream side of the bars. Front discharge of screenings may be preferable to back discharge as any screenings lost in handling are upstream of the screen and therefore will again be subject to the chance of removal.

The Hydroscreen (Fig. 6.7) and Hydrasieve represent a modern development of the bar screen in which the bars are arranged horizontally instead of vertically and have much closer spacing (0.02 inches to 0.06 inches (or 0.05 or 0.15 cm)). In both cases, the bars are made of stainless steel wedge wire supported in a framework. Incoming water is delivered to the top of an inclined screen. As the wastewater runs downward over the outer inclined screening surface, water drops through the screen to the back and is collected in a trough while intercepted solids fall to the bottom of the incline for disposal.

The only cleaning mechanism is the force of the effluent water which sweeps the intercepted material off the face of the screen. Manual cleaning by brushing or hosing is required at intervals, the frequency depending on the nature of the waste.

6.211 Moving Screens (Fig. 6.8)

The Rotostrainer incorporates screening media made of stainless steel wedge wire similar to that used on the Hydroscreen. In this case, the screening media is mounted on a horizontal cylinder which rotates continuously. The cylinder is carried in a supporting structure with external bearings. The supporting structure also forms the feed box for the influent to run outwards over the top of the horizontal rotating cylinder. The strained water falls through the screening media into the inside of the cylinder and out through the bottom of the screen into a collecting trough. The force of the falling water is sufficient to clean off the screen. A wiper or *DOCTOR BLADE*[5] is fitted to skim off intercepted solids and drop the debris into a collecting trough for disposal.

Figure 6.8 shows various types of Rotostrainer installations. If required, the Rotostrainer can be fitted with an optional internal backwash system which delivers either steam or hot water under relatively high pressure to the interior of the cylinder. The steam or hot water removes any material that may not have been removed by the natural backwashing action.

Screenings from the Rotostrainer are usually collected and discharged to a disposal point by a trough or conveyor system. From here they may be pressed before disposal to landfill, incineration or byproduct recovery depending on the type of screenings.

Another type of drum or cylindrical screen (Figure 6.9) uses woven wire mesh with apertures (holes) between ⅛ inch and ½ inch (0.3 and 1.3 cm), mounted on the periphery. In this unit, the effluent flows into the inside of the drum and gravitates through the screening media to the outside. The rotation of the drum is used to bring the intercepted solids up underneath a row of backwash jets spaced across the top outside of the drum. These jets spray downwards

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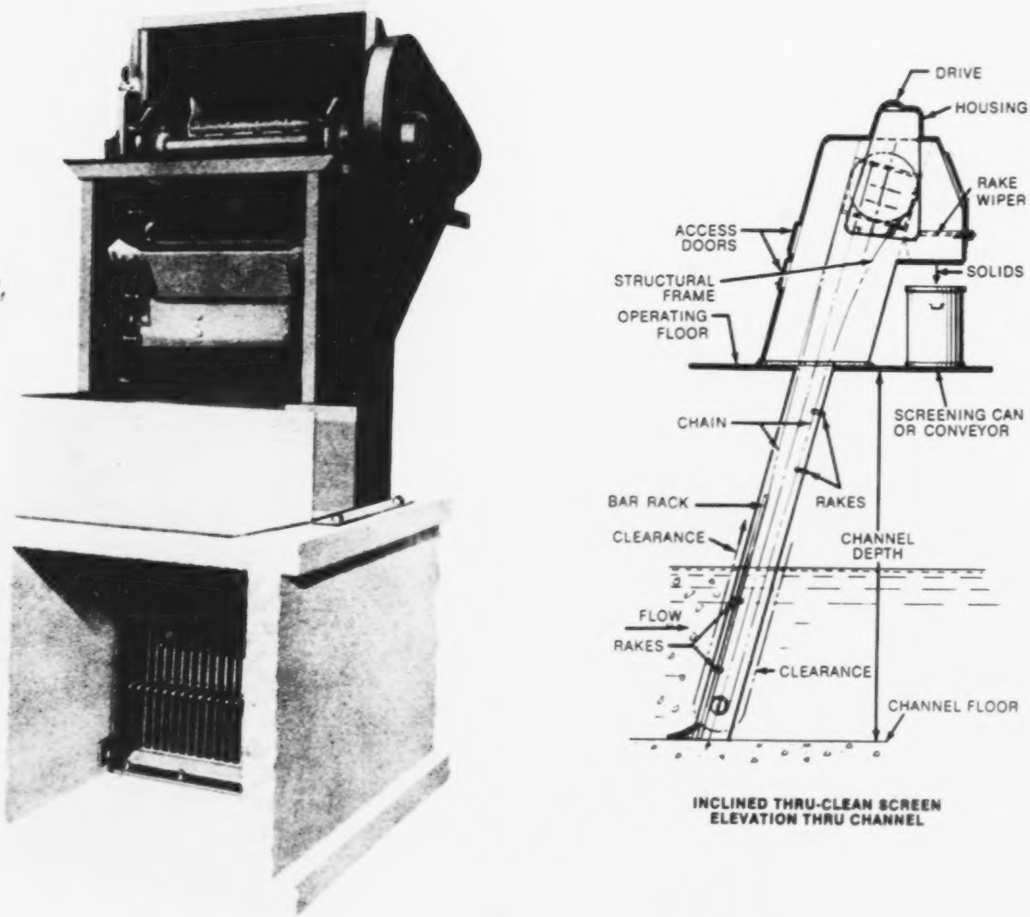
[5] *Doctor Blade. A blade used to remove any excess solids that may cling to the outside of a rotating screen.*



Thru-clean screen viewed from upstream side. Head shaft housing has been removed to show cycle of rake movement.

DRIVE
HOUSING
RAKE WIPER
ACCESS DOORS
STRUCTURAL FRAME
SOLIDS
OPERATING FLOOR
SCREENING CAN OR CONVEYOR
CHAIN
RAKES
BAR RACK
CLEARANCE
CHANNEL DEPTH
FLOW
RAKES
CLEARANCE
CHANNEL FLOOR

INCLINED THRU-CLEAN SCREEN ELEVATION THRU CHANNEL

Fig. 6.6 Bar screen

(Permission of FMC Corporation, Environmental Equipment Division)

Screen Flexibility
The three individual screen panels are designed for easy removability allowing for:

- quick changeover to accommodate any variation in solids concentrations or for instantaneous cleaning.
- a progressive screen space opening profile can be achieved by varying the screen space opening at any one of the three locations.

Screen Construction
Corrosive resistance and durability is built into the all stainless steel Hydroscreen.

Three distinct screen angles allow the solids to travel uniformly down the screen face, becoming progressively drier until they are discharged from the lower edge.

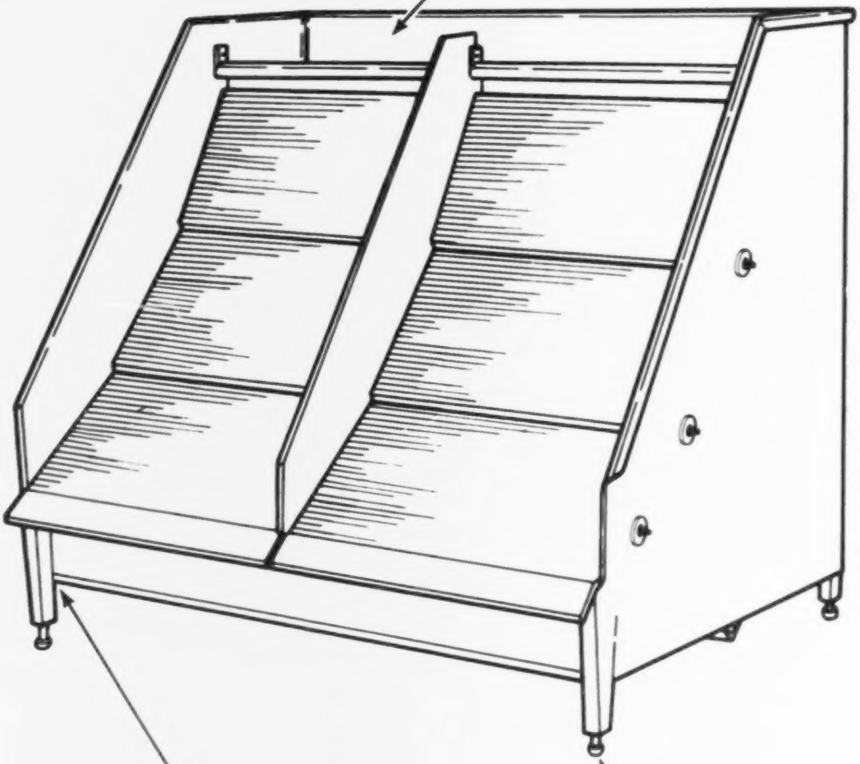
Screen Installations
The three overlapping screens fit snugly into the chassis preventing any bypass of solids to the effluent.

Screen Bar Spacing
Units are available with wire space openings from 0.010"/0.25mm to 0.100"/2.50mm.

Optional Features

- Top influent feed
- 304 stainless steel
- Flanged inlets and outlets
- Side cleanout panel
- Fiberglass construction in selected models

Headbox
The headbox is specially designed to receive and moderate high inflow velocities. The influent flows evenly over a weir onto the screen surface.



Rugged Construction
Available in all 316 stainless steel continuous weld construction models.

Leveling Pads
Heavy duty level pads provide quick and permanent leveling adjustment.

Fig. 6.7 Hydroscreen
(Permission of Hycor Corporation)

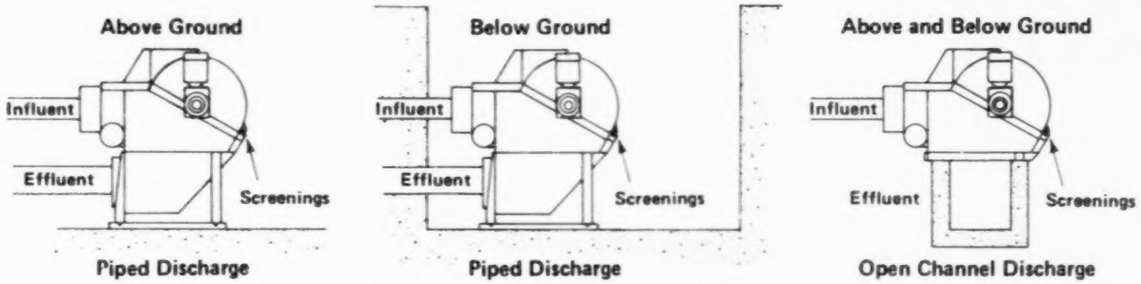


Fig. 6.8 Rotostrainer type of moving screen

(Permission of Hycor Corporation)

continuously and flush the debris into a collecting hopper which runs parallel to and along the axial length of the drum. From here the solids flow by gravity to disposal. A screw conveyor is sometimes used in the hopper to assist in removing solids.

These screens are best suited to installations where a fixed water level can be maintained. The screen is supported by two bearings and driven from one end. The open end is sealed against the stationary frame by means of a rubber seal to prevent bypassing of the liquid.

The main parts of the drum screen are identified on Figure 6.9. The drum screen is operated under open gravity flow conditions using inlet and outlet channels to bring the water into the drum and take it away on the downstream side. Backwash water is usually pumped from the downstream side, or from a clean water (low or without suspended solids) source. Arrangements must be made for conveying away screenings and wash water discharge.

The drum screen is sometimes fitted with a splash cover or hood containing an inspection door. In other cases the drum is installed in a superstructure to protect the equipment and provide the best operating conditions.

A disc strainer (Figures 6.10 and 6.11) is similar to the drum strainer described above except that a disc is used in place of a drum. The disc carries the coarse screening media, usually woven wire cloth, and rotates through the flowing liquid which gravitates (drops) through the screen. Spray jets are arranged radially above the water level to wash off the screenings into a hopper and continuously clean the mesh.

Figure 6.10 is a drawing of a typical disc screen and identifies the main parts of the design.

As in the case of the drum screen, a rubber lip seal is required to prevent bypassing of the water around the screen. The screen is supported on a rotating shaft mounted in two bearings above the fixed water level. Flow capacity of the screen depends upon the size of mesh fitted and may be calculated using a head loss not exceeding one inch (2.5 cm) of water.

The band screen or traveling screen (Figure 6.12) is another type of moving screen which uses panels of coarse wire mesh or perforated plates fixed to a chain which is carried over top and bottom rollers in the form of an endless belt. The bottom of this screen is immersed in the flowing water and the top moves through a hood in which are mounted jets that spray through the screen and force solids into a backwash collecting hopper. The movement of the screens is used to lift debris from the flowing water and to clean the screening media.

Traveling screens are used where water levels are variable as in the case of river water intakes. Their use is not so common in wastewater treatment.

Figure 6.12 identifies the main parts of the traveling screen. Note that it is installed in a concrete channel through which water flows under gravity. A seal must be provided between the moving screen and the side of the channel to prevent leakage. The fineness of the screen material is limited in practice by the need to have openings between the screen panels in order to allow deflection of the panels as they move over the rollers. A channel must be provided to convey away the waste material washed from the screen.

All moving screens may run continuously at constant speed or variable speeds which can be controlled automatically by the upstream channel level, flow level, or head differential through the screen.

6.212 Microscreens (Figure 6.13)

Microscreens are similar to the coarse drum screen described above except that the straining media is much more finely woven with apertures (holes) between 2 and 60 *MICRONS*.[6] The fabric (Figure 6.14) can be made of stainless steel or polyester threads and is mounted on the periphery of a continuously rotating drum. Microscreen threads may also be made of nylon (Nitex), polypropylene, polyethylene, Teflon, copper, brass, bronze, nickel, aluminum and other materials. The rotating drum is carried on submerged bearings and supports the straining media. The purpose of drum rotation is to present a clean surface of the media to the water to allow flow to continue. The rotating drum brings the dirty fabric under the backwash system at regular intervals. Sometimes a supplementary cleaning system is used, such as ultraviolet irradiation, to inhibit the growth of biological slimes.

The rotation of the drum also lifts intercepted solids from the wastewater and deposits these solids in a hopper supported inside the drum. Intercepted solids are washed away by backwash water that runs from the hopper by gravity into the disposal system.

The drive unit with variable speed is used to rotate the drum. The speed control can be manually or automatically operated. In the case of automatic control, head loss across the screen is normally used for regulating drum speed.

Figure 6.13 identifies the main parts of the microscreen which is usually installed in open gravity flow channels to allow water to percolate through the drum form inside to outside. The top of the wash water hoppers are in air above the water surface to receive the intercepted solids as they are washed off the inside of the mesh. Backwash from a clean source is brought to the header pipe which runs above the top of the drum in an axial direction. A peripheral seal is provided to prevent bypass of the water being strained.

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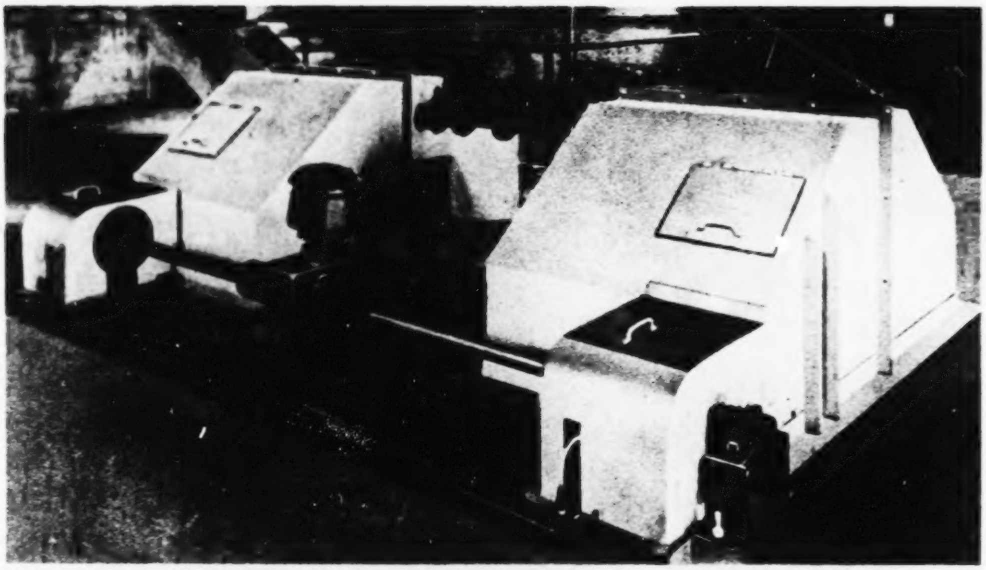
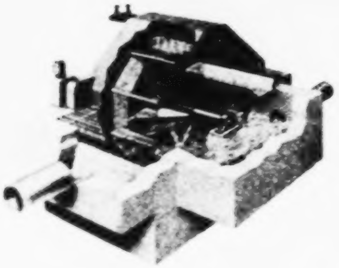
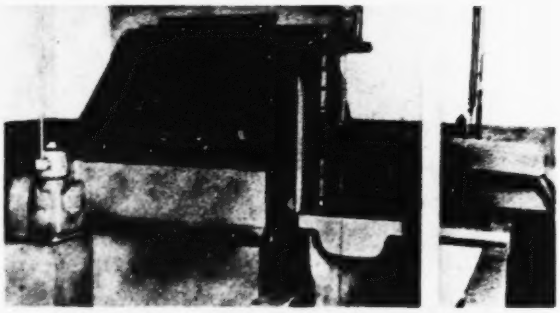
[6] *Micron (MY-kron). A unit of length. One millionth of a meter or one thousandth of a millimeter. One micron equals 0.00004 of an inch.*



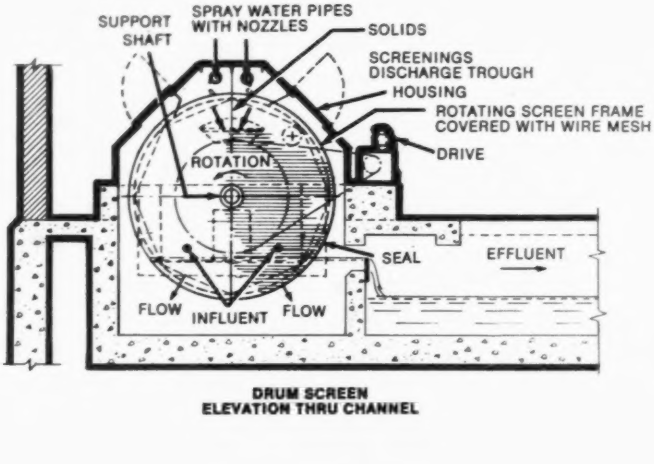
Industrial installation of a drum screen utilizing a dewatering screw conveyor.



Cutaway view of revolving drum screen available with stainless steel cloth of 2 to 60 mesh or finer and up to 10' in diameter.



Encased revolving drum screen separates debris from river intake water at a woolen mill. Driven by ½ horsepower motorized worm gear drive, a maximum flow of 2700 gallons per minute is screened.

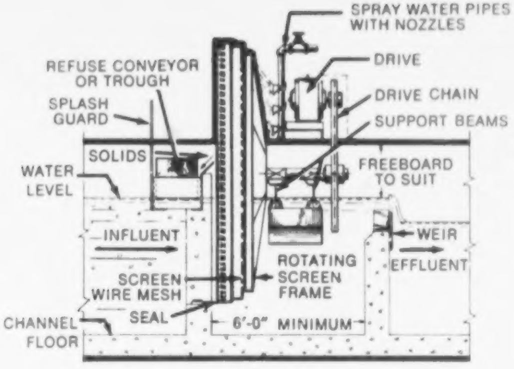

SUPPORT SHAFT
SPRAY WATER PIPES WITH NOZZLES
SOLIDS
SCREENINGS DISCHARGE TROUGH
HOUSING
ROTATING SCREEN FRAME COVERED WITH WIRE MESH
DRIVE
ROTATION
SEAL
EFFLUENT
FLOW
INFLUENT
FLOW

**DRUM SCREEN
ELEVATION THRU CHANNEL**

Fig. 6.9 Revolving drum screen

(Permission of FMC Corporation, Environmental Equipment Division)

Revolving Disc screen installed at a municipal wastewater treatment plant.


SPRAY WATER PIPES WITH NOZZLES
REFUSE CONVEYOR OR TROUGH
DRIVE
DRIVE CHAIN
SPLASH GUARD
SUPPORT BEAMS
SOLIDS
WATER LEVEL
FREEBOARD TO SUIT
INFLUENT
WEIR
ROTATING SCREEN FRAME
EFFLUENT
SCREEN WIRE MESH
SEAL
CHANNEL FLOOR
6'-0" MINIMUM

DISC SCREEN
ELEVATION THRU CHANNEL

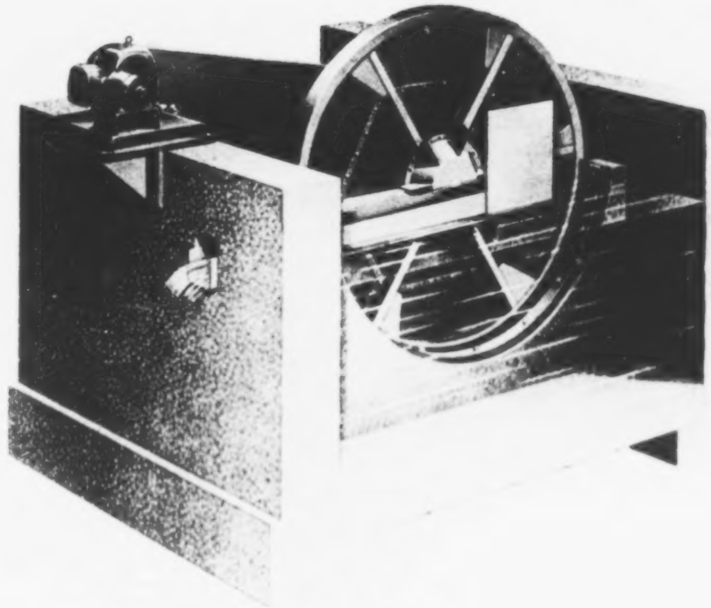
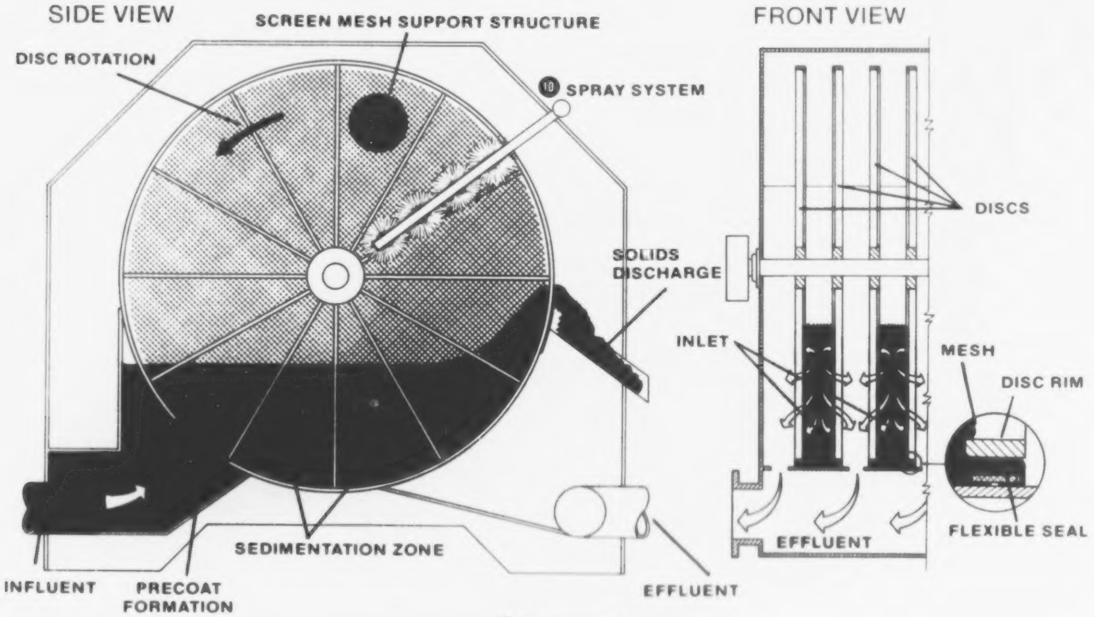
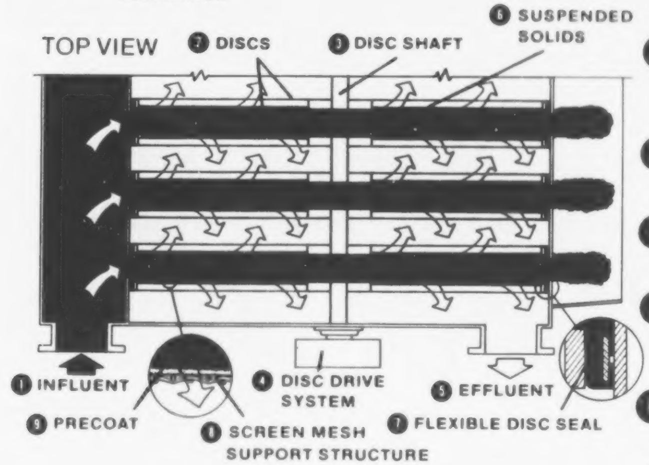


Fig. 6.10 Revolving disc screen

(Permission of FMC Corporation, Environmental Equipment Division)

Operation and Construction Details


SIDE VIEW
SCREEN MESH SUPPORT STRUCTURE
DISC ROTATION
⑩ SPRAY SYSTEM
SOLIDS DISCHARGE
SEDIMENTATION ZONE
INFLUENT
PRECOAT FORMATION
EFFLUENT
FRONT VIEW
DISCS
INLET
MESH
DISC RIM
FLEXIBLE SEAL
EFFLUENT


TOP VIEW
② DISCS
③ DISC SHAFT
⑥ SUSPENDED SOLIDS
① INFLUENT
⑨ PRECOAT
④ DISC DRIVE SYSTEM
⑤ EFFLUENT
⑧ SCREEN MESH SUPPORT STRUCTURE
⑦ FLEXIBLE DISC SEAL

Flow Description

The process or waste water enters the energy absorbing inlet chamber before being channeled between the sets of rotating discs The mesh covered discs capture the suspended solids while allowing the water to flow out to discharge. The solids remaining behind form a precoat material which aids the filtration effect As the solids level between the discs builds up, a portion is wasted through the solids discharge opening in the front of the Discostrainer

The continuous rotating mass of solids carried on the revolving discs falls back from the discs as they reach the highest point of travel This creates a self-cleaning scouring action, adding greatly to the non-blinding characteristics of the disc straining process

Component Parts

① Influent

Inlet headbox has a specially designed energy dissipating baffle which feeds the wastewater between each pair of discs

② Discs

The discs are arranged in pairs The smallest unit has one pair of discs, the largest 10 pairs The discs vary in size from 39" dia to 71" dia

③ Disc Shaft

Discs are mounted on a horizontal stainless steel shaft which is supported at each end by pillow block bearings

④ Disc Drive System

A shaft mounted variable speed direct drive system rotates the discs at 5 to 15 rpm

⑤ Effluent

Screened liquid flows radially out from between the discs into an effluent chamber which channels it to a common discharge pipe

⑥ Suspended Solids

As the suspended solids agglomerate, a waste portion is discharged through the front opening of the Discostrainer

⑦ Disc Seals

The discs rotate in a specially contoured chamber A mechanical seal prevents any leakage of liquid solid between the outside rim of the disc and the contoured chamber Thus the total influent must pass through the disc screening mesh

⑧ Screen Mesh Support Structure

The fine screen mesh is supported on each disc by a rugged, stainless steel radial structure and heavy duty woven mesh backing which prevents the screen from bowing or bulging Available from 45 to 425 microns

⑨ Precoat

The precoat filtration aid media is formed by the solids captured between the discs This insures a better removal efficiency of fewer suspended solids

⑩ Spray System

An integral spray system can be provided as an optional extra It consists of a centrifugal pump and backwash spray header arrangement The solids washed off the discs are removed with the excess solids discharged from the Discostrainer

Fig. 6.11 Disc strainer

(Permission of Hycor Corporation)

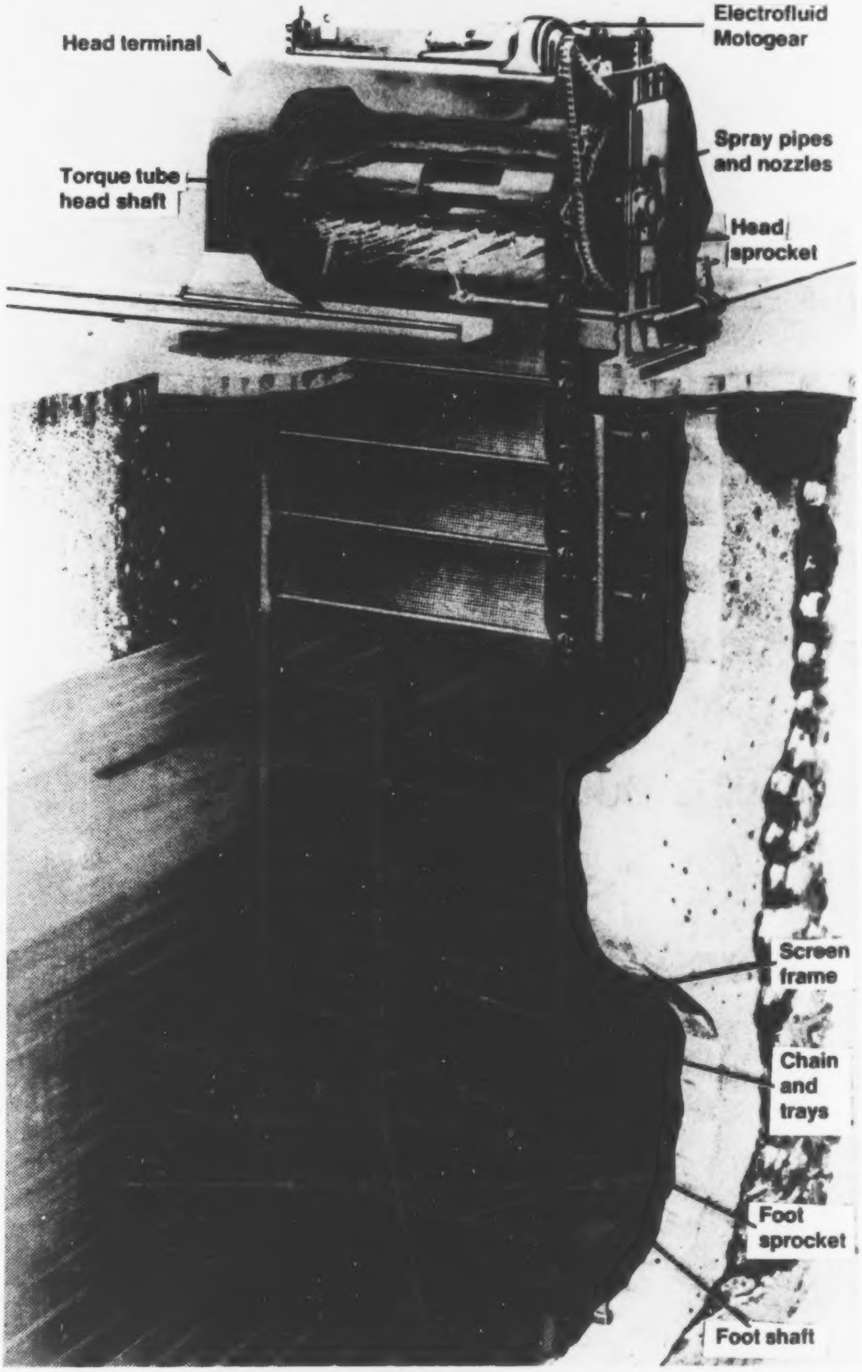

Head terminal
Electrofluid Motogear
Spray pipes and nozzles
Torque tube head shaft
Head sprocket
Screen frame
Chain and trays
Foot sprocket
Foot shaft

Fig. 6.12 Thru-flow type traveling screen

(Permission of FMC Corporation, Material Handling Systems Division)

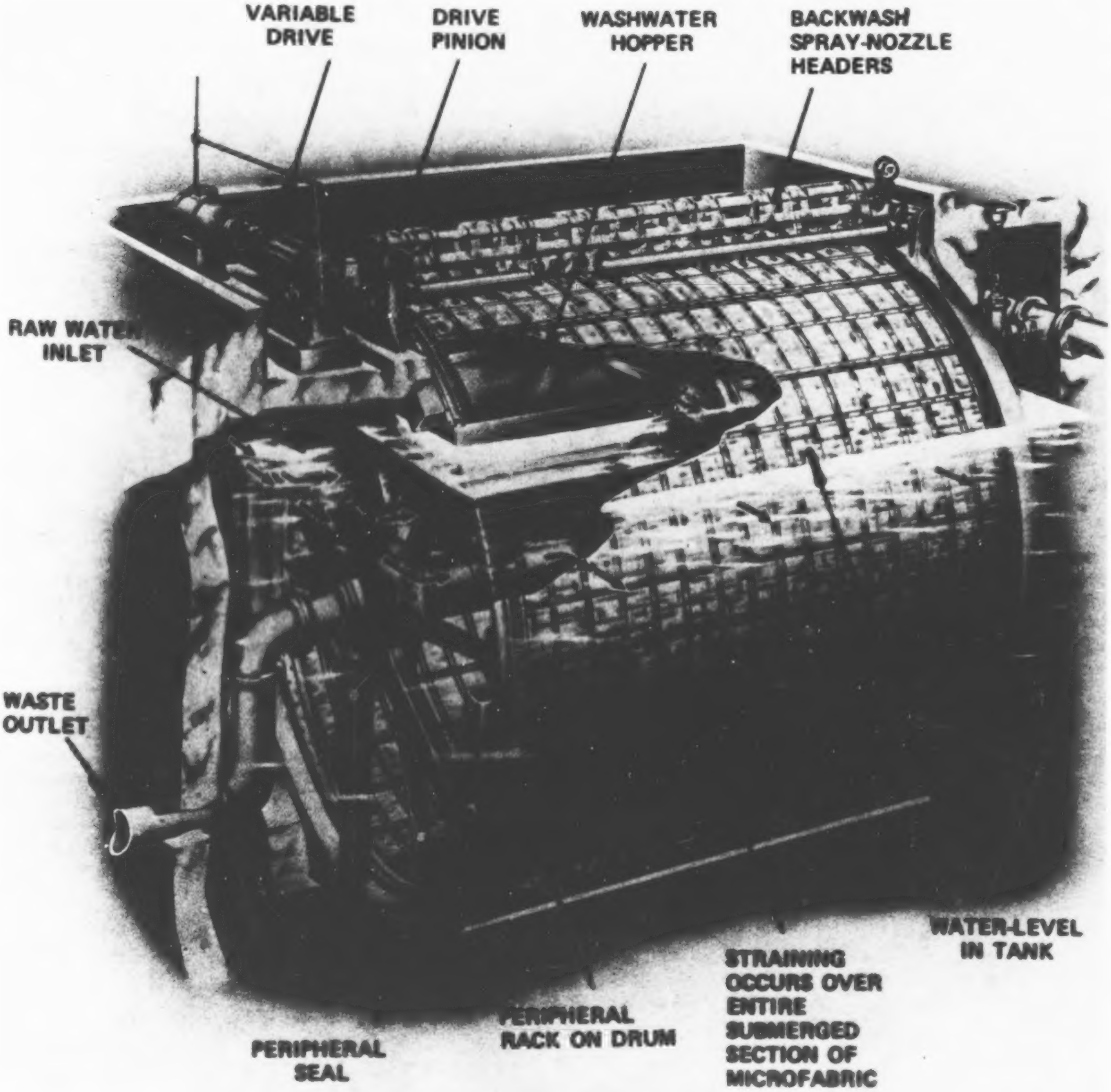

VARIABLE DRIVE
DRIVE PINION
WASHWATER HOPPER
BACKWASH SPRAY-NOZZLE HEADERS
RAW WATER INLET
WASTE OUTLET
WATER-LEVEL IN TANK
STRAINING OCCURS OVER ENTIRE SUBMERGED SECTION OF MICROFABRIC
PERIPHERAL RACK ON DRUM
PERIPHERAL SEAL

Fig. 6.13 Microscreen

(Permission of Crane-Cochrane)

6.213 Mechanical Equipment

In all cases, the screening media must be of sufficient strength to withstand the hydraulic pressure created by head loss as solids are intercepted on the screens. In the case of wire mesh screens, a support system is sometimes used. The material should also be *NONCORRODIBLE*[7] and preferably of the type which assists cleaning such as wedge wire. The bars in coarse screens are often made wedge-shaped for this purpose.

The structure used to support the straining media varies depending upon whether a screen is stationary or moving. In the case of bar screens it consists of structural steel sections embedded in the concrete sides of the channel. In the case of the Hydrasieve, the structure incorporates the feed box and is self-supporting.

In the case of moving coarse screens, bearings will be involved either carrying top and bottom rollers in the case of band screens or supporting the disc or drum in the case of rotary strainers. Some difficulty in design is presented by submerged bearings. Ideally, the bearings are lubricated and should be placed above the water surface. This may not be possible with the bottom roller on a band screen so water-lubricated bearings are installed.

For moving screens, some sort of seal is needed between the moving and stationary sections to prevent the passage of solids in suspension. All screens require some sort of cleaning mechanism. In its simplest form, this is a manually operated rake. Bar screens are often inclined to assist in removing the intercepted solids. A walkway is provided across the top of the channel to receive the solids so they can be removed to one side for disposal.

The automatically operated cleaning mechanism fitted on some bar screens consists of heavy metal teeth which project through the bars from front or back and are operated by a toggle (a projecting knob or arm) which brings them into contact with the intercepted solids allowing them to sweep the bars clean and lift the solids into a hopper for disposal.

The drive mechanism for the cleaning rake is usually an electric motor with reduction gear and chain drive. The starter for the electric motor may be controlled by a time switch or the differential pressure across the screen. This type of cleaning mechanism can be applied to vertical or inclined bar screens.

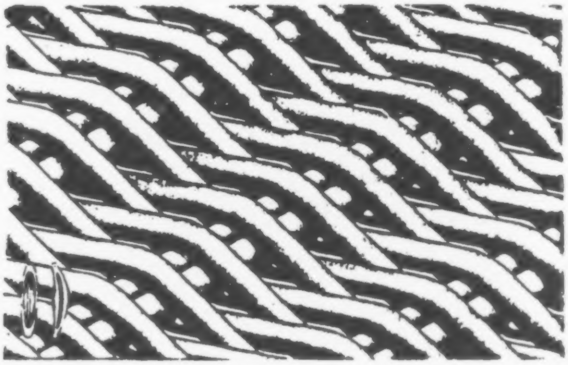


Fig. 6.14 Isometric drawing of microfabric with typical diatom (Cymbella) shown against the fabric

The cleaning system of moving screens usually incorporates nonclog design backwash jets. These are supplied with clean water (low or without suspended solids) under 30 to 60 psi (2.1 to 4.2 kg/sq cm) pressure. They create a fan tail which spreads across the entire width of the screen. Sometimes two rows of jets are employed and may be assisted by brushes or doctor blades (wipers).

When jets are used to clean the screen, a hopper must be placed behind the screen opposite the jet system. This will collect the solids which are washed off the coarse mesh. The solids may then travel by gravity into a pipe for disposal or be removed by a screw conveyor.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 450.

6.2C List the different types of screens?

6.2D What types of controls can be used to clean screens?

6.2E Clean water used to backwash screens and filter media must be low ____________.

6.2F How can the speed of a variable-speed moving screen be controlled?

6.22 Safety Procedures

High risk activities include manual cleaning of the screens or microscreens and maintenance of associated machinery. If the screens are installed indoors, adequate ventilation must be provided to prevent maintenance personnel from being overcome by fumes. Problems can develop from toxic gases such as hydrogen sulfide, explosive conditions or a lack of oxygen.

Use a gas mask (hose type or air breathing apparatus) or provide adequate ventilation and monitor the atmosphere when entering enclosed areas because of the possibility of noxious fumes. Other sources of danger include falling into channels, slipping on slimy walkways, getting caught in moving machinery or coming into contact with exposed electrical wiring. Whenever you discover exposed electrical wiring, have an electrician correct this hazard immediately.

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[7] *Noncorrodible. A material that resists corrosion and will not be eaten away by wastewater or chemicals in wastewater.*

Channels adjacent to the screens should be roofed over and appropriate manholes must be provided with corrosion-resistant rungs or steps.

Work in basements or tanks should not be undertaken without checking to be sure isolating valves are properly closed, drainage valves are open, adequate personnel are present, proper lighting is provided and equipment such as spark-proof tools, rubber boots, safety belts and rubberized gloves are available.

Work should never be undertaken in an area normally open to traffic without an adequate number of barriers and signs. Also, vehicles should have a rotating beacon on top of the cab. All workers should wear hard hats and a red vest.

Before draining down a sump, wet well, channel or tank to enter and service moving machinery, be sure to stop the machinery and remove the contact breaker from electrical starters. Switchboards and areas of operation must be kept well lighted at all times. Walkways, stairs and ladders should be kept clean, free from grease, oil and ice and adequately lighted. Guards should be used over rotating machinery. Nonslip surface should be provided on the edges of channels. Adequate space for servicing should be provided around machinery and control panels.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 450.

6.2G If an oxygen detector indicates insufficient oxygen, how can this problem be corrected?

6.2H What kinds of precautions should be taken before working in an area open to traffic?

6.23 Operating Procedures

6.230 Start-Up Procedures

Before starting any screening equipment, go through these start-up procedures and check all items listed that apply to your facility plus any other items that are unique to your facility.

1. Be sure that all components are in place and any temporary packing has been removed.
2. Examine oil levels and grease points.
3. Check for personnel in area, observe safety precautions.
4. While chambers are dry, try movement of machinery.
5. If equipment can be operated dry, allow it to run for a short period.
6. Inspect equipment alignments and make adjustments to gaskets, sprockets, drive chains, rakes and belts.
7. Operate through several cycles. Inspect alignment and listen for excessive noise. Watch for erratic motion.
8. Check automatic controls, if fitted.
9. While machinery is in slow speed, open chamber inlet valve gradually to admit water at a slow rate.
10. Watch for any excessive debris being washed in, in which case speed up screen movement and cleaning mechanism.
11. Determine head loss across screen. Guard against surges of flow. Continue to regulate inlet valve until desired head loss is achieved.
12. If fitted, operate backwash system as soon as possible and check operation of jets.
13. Check to see if debris and solids are being flushed off the screen and are running to disposal.
14. In the case of rakes, check to see that the rake is scraping the bar screen clean of debris.
15. Check gaskets, water seals, and also look for leaks, bypassing and irregular motion. Make adjustments as necessary.
16. If fitted, check automatic controls in functioning mode.
17. Equipment should now be operating normally. Continue to observe and regulate equipment as necessary for several hours.

If the correct start-up procedures have been used, the coarse screen or microscreen will function correctly by treating the required rate of flow without an excessive head loss.

6.231 Normal Operation

The main parts to be checked regularly include the screening media which should be examined for cleanliness and structural soundness, the cleaning system which may consist of backwash spray jets or a mechanical rake, the drive unit if fitted, and other moving machinery. The effectiveness of seals and gaskets as well as the strength and stability of supporting framework should be inspected regularly. Inspect the screening media for *BLINDING*[8] or blocked grids. Operational data should be recorded on a printed form and returned in writing to the supervisor. A sample form is shown in Figure 6.15.

Sampling of the effluent should be carried out before and after the screening media. Grab samples are usually used, although continuous monitoring is preferable. Flow rates should be observed and recorded. Head loss, rate of rotation or speed of the screen should be noted every day. Your sampling program must be designed to meet the monitoring and reporting requirements specified in your sewer-use ordinance and NPDES permit.

Try to relate the flow rate to the head loss observed using the proper hydraulic formula in either Section 6.251, "Design of Coarse Screens," or Section 6.252, "Design of Microscreens." This will indicate the degree of plugging of the screening media. In the case of microscreens, a more complicated procedure based on the concentration of solids in suspension is necessary.

6.232 Abnormal Operation

Abnormal conditions of the screening media are shown by heavy plugging which will lead to an increase of head loss and reduction of flow rate. The cleaning system may be examined visually. Backwash jets should present a smooth fantail extending across the straining surface operating continuously at adequate pressure. Seals and gaskets should be inspected. Abnormal conditions of moving machinery are often identified by erratic movements or unusual noises. Wear on bearings should be checked when the equipment is drained down.

Overloading of the upstream processes can cause difficulties with operation of microscreens. There are limits to the

---

[8] *Blinding. The clogging of the filtering medium of a microscreen or a vacuum filter when the holes or spaces in the media become sealed off due to grease or the material being filtered.*

OPERATOR

Name ____________________
Date ____________________
Shift ____________________
Time ____________________
Weather ____________________

FLOW

Rate ____________________
Temp. ____________________
Depth ____________________
Drum Speed ____________________
Screen Submergence ____________________
Head Loss ____________________
Other ____________________

BACKWASH
(or rake)

Press ____________________
Flow ____________________
Other (Supplemental cleaning) ____________________
____

ELEC. POWER INPUTS		Auto	Manual
	Drive	______	______
	Backwash	______	______
EFFICIENCY		Before	After
	S.S.	______	______
	B.O.D.	______	______
	Other (oil, grease)	______	______
		______	______

Fig. 6.15 Sample operational report sheet

amount of suspended solids which can be handled at the design flow rate. Figures 6.16 and 6.17 illustrate the relationship between suspended solids and the flow rate.

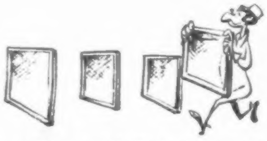
A similar restriction applies to coarse screens, but the limits are not so critical (Section 6.251 and 6.252). Abnormal conditions in the waste stream are shown by excessive flow rate and concentrations of solids, large trash or floating objects. This can damage screens either by impingement or by creating excessive differential head which will rupture the screening material. The cause of abnormal conditions is often increased flow rate from rain storms. Sometimes accidental spills or discharges can create upsets and malfunction of upstream processes.

Wastewater conditions can be checked visually and flow indicators will give warning of increased flow rate. A differential head alarm on the screen will also measure and warn of excess flows or solids. If these conditions occur, attempts should be made to improve upstream operating conditions. At the same time, cleaning of the screens should be increased. In the case of coarse screens, this means cleaning continuously if manually operated, or speeding up the device if automatically operated. In the case of microscreens, the speed of rotation and the backwash pressure should be increased.

6.233 Operational Strategy

If more than one screen is available, place the number of screens on line needed to handle the flows and solids to be treated. Operate each screen within its design hydraulic, solids loading, and differential head range. When solids loadings change, adjust procedures or equipment for cleaning the screens accordingly. Another approach is to keep all screens operating in order to keep fabric clean and ready for use. The procedure you develop for your screens will depend on influent conditions, costs of operation, and effluent requirements.

6.234 Shutdown Procedures



1. Close chamber inlet valve.
2. Open chamber drains.
3. Allow water level to drop slowly while regulating speed of machinery to prevent excessive differential head. Keep backwash turned on until level reaches within 1 foot (30 cm) of pump suction. Then close down backwash system and shut off backwash pump.
4. Allow water level to continue falling while maintaining differential head within safe limits.
5. When chamber is empty, hose off all screen material with clean water (low or without solids).
6. When all solids are washed out of the chamber and the media is clean, adjust drive unit to minimum speed setting and turn off power supply.

   NOTE: Screening media should be left in a clean condition, otherwise it will dry out dirty and be difficult to clean before putting screen into service next time.

   If shutdown is only for a brief period, it may not be necessary to drain chamber completely, as long as machinery is kept in motion. This will prevent the screening media from becoming plugged.

Evaluation of whether correct shutdown procedures have been used will be shown by the screen or microscreen being in a clean condition when the chambers are dry and empty. An examination of the mesh/screening material should be made to insure that it is perfectly clean and does not dry out in a dirty condition.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 450.

6.2I During start-up, what kind of a check is made on the solids and debris?

6.2J List the major items that should be inspected during the normal operation of a microscreen.

6.2K Heavy plugging of a screen could be caused by what factors?

6.2L How would you determine if correct shutdown procedures had been used for a screen or microscreen?

6.235 Troubleshooting

Table 6.1 lists the problems most frequently encountered when operating screens and microscreens. Once the trouble and cause have been identified, the correct solution can be selected.

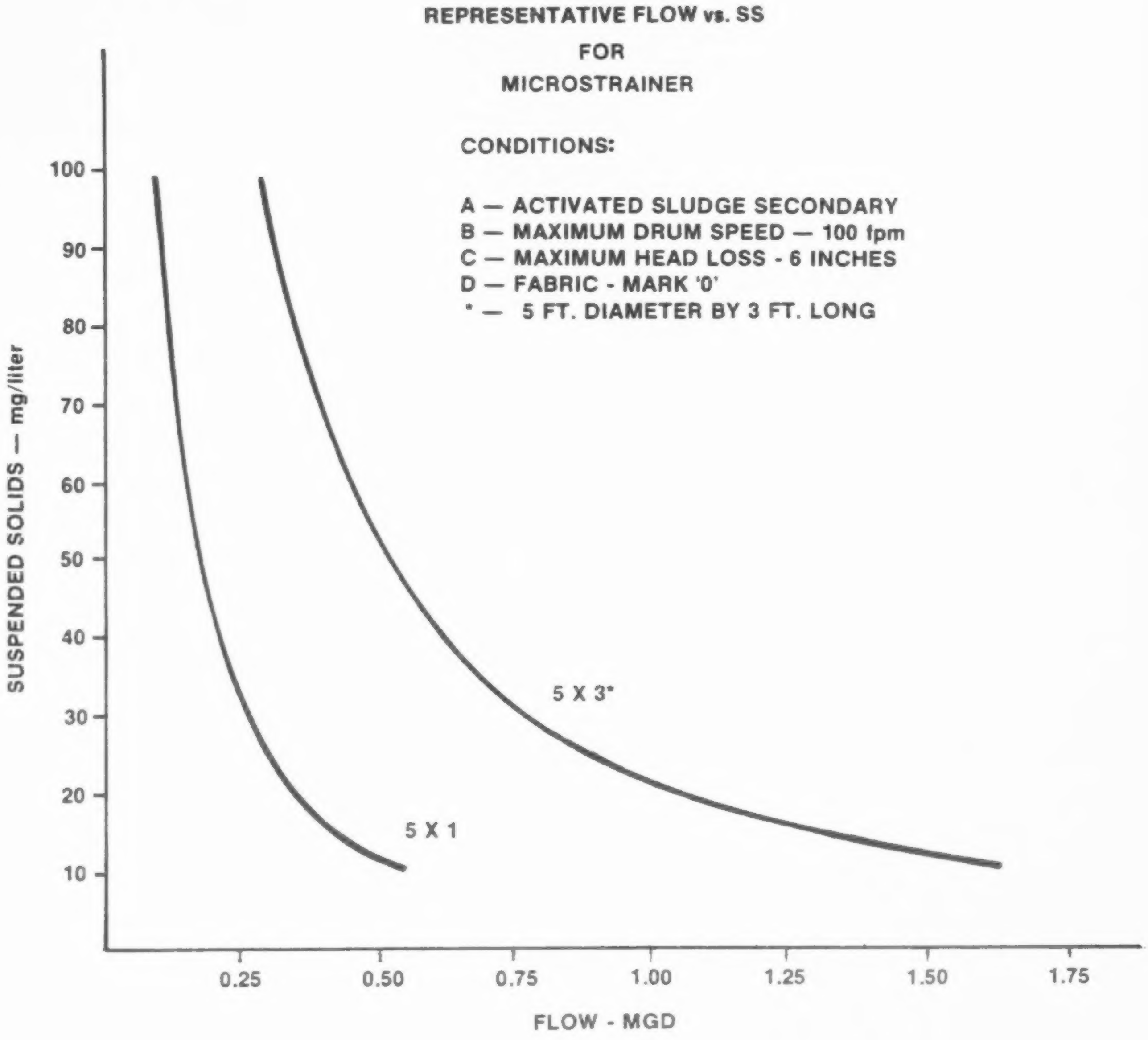


Fig. 6.16 Recommended flow rate for various suspended solids loadings

(Permission of Cochrane Division-Crane Co.)

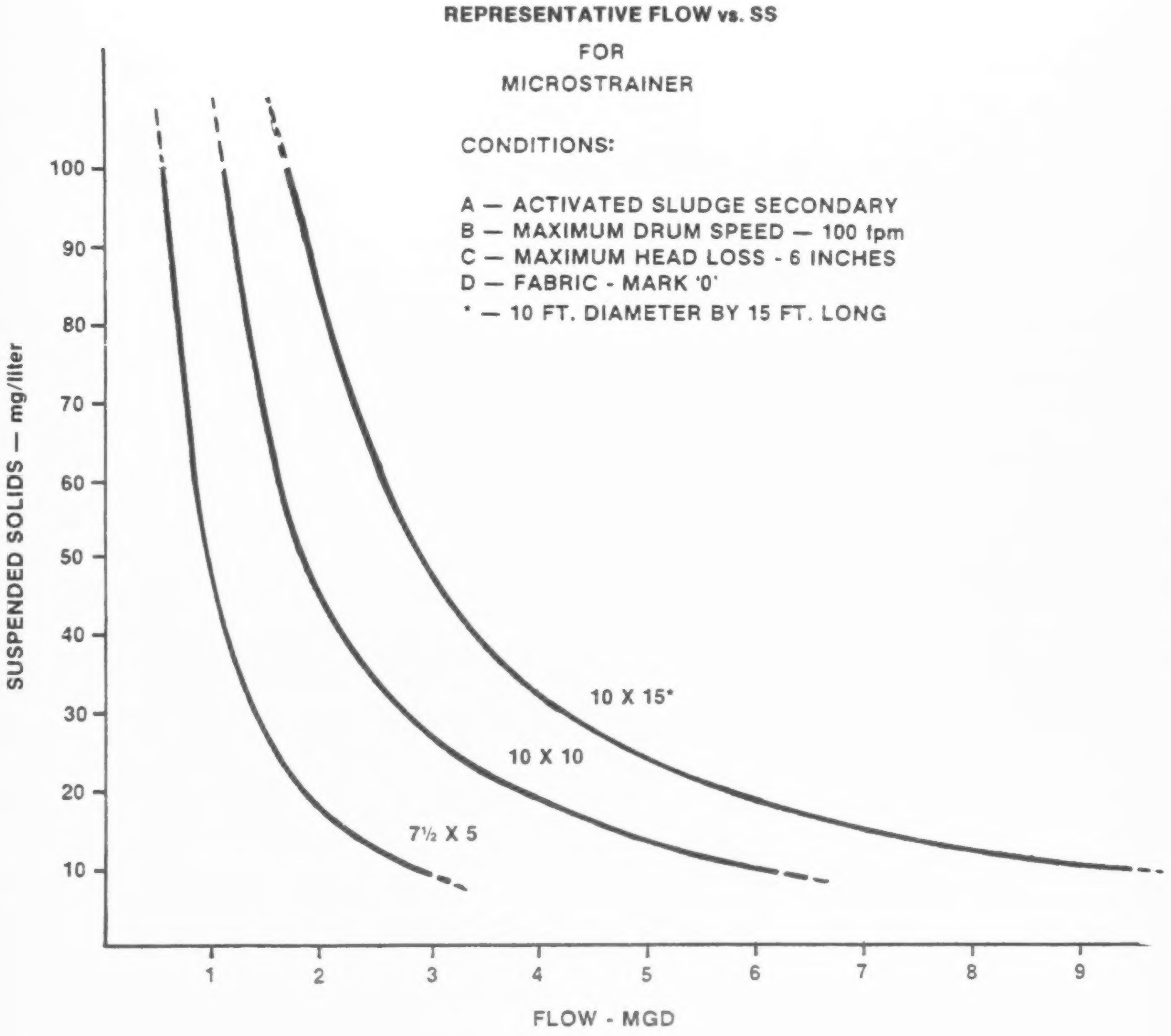


Fig. 6.17 Recommended flow rate for various suspended solids loadings

(Permission of Cochrane Division-Crane Co.)

6.24 Maintenance

6.240 Preventive Maintenance

Stationary screens should be examined visually each day to check the condition of the screening media and to note whether there are any obstructions to the flow. Also look for objects lodged in the screens which should be removed or rocks at the bottom that could jam or restrict rake travel. Also the structural condition of the media should be checked and any defects should be repaired.

If there is a mechanical cleaning device, it should be activated each day to make sure it operates freely without jamming.

Greasing points should be lubricated according to manufacturer's recommendations and any unusual noises or actions examined for defects. Manufacturers' literature should be used in carrying out examination and repair to moving machinery.

In the case of moving screens, band, disc or drum-type screens, the above points should be checked and, in addition, the movement of the screens must be checked using manufacturers' manuals to lubricate and repair as necessary.

If a spray system is fitted, this should be operated manually at high pressure for a short period to free any potential blockages and assist in cleaning the screen.

If the speed of the band, disc or drum screen is manually adjustable, it should be operated at various speeds for a short period while the high pressure wash is turned on. At longer intervals, the structural soundness of the screening media should be examined after draining down and isolating each chamber in turn. This can be done using a flashlight to closely inspect the media and repair any holes, tighten up securing screws and check for corrosion.

Wear on moving parts should be inspected, including brushes, bearings, and sealing gaskets. Manufacturers' instructions should be used for this purpose. At longer intervals it will be necessary to clean, scrape and paint the supporting structure of the screen.

TABLE 6.1 SCREENING AND MICROSCREENING TROUBLESHOOTING CHECKLIST

PROBLEM	CAUSE	SOLUTION
1. No wastewater flowing through screen	Inadequate cleaning	Clean dirty screen using chemicals if necessary.
	Overload conditions, too many solids	Improve performance of upstream processes.
	No wastewater flowing to screen	Check if upstream channel is blocked.
	Inadequate depth of water	Increase depth by suitable adjustment of flow.
2. Noisy movement of screen	Bearing troubles	Remove and repair or replace bearings.
	Inadequate grease	Insure adequate grease is reaching all points.
	Insufficient oil	Check depth of oil in gear boxes.
	Drive mechanism faulty	Check condition of chains and gears.
3. Suspended solids passing through screen	Ruptured seal	Repair or replace seal.
	Ruptured screen	Repair or replace screen.
	Overflow and bypassing of wastewater	Reduce overflow conditions by improved upstream operation.
	Corrosion of screen	Check if corrosive chemicals in water or backwash.
	Aperture size too large for duty	Change screen material.
4. High head loss across screens	Screen plugged	Clean screen, using chemicals if required.
	Too high a concentration of solids in wastewater	Improve upstream operation to reduce suspended solids concentration and/or flow rate.
	Too high a rate of flow	Step up rate of cleaning and/or speed of drum.
	Inadequate cleaning	Increase backwash pressure.
5. Screening mechanisms stop moving	Electrical power failure	If electrical overload has occurred, replace fuse or reset relay.
	Drive failure	May have interference in movement, if so, remove obstruction.
	Bearing failure	Check if chain drive and/or gears are moving freely. Drum bearings should have adequate lubrication.

6.241 Maintenance Schedule

DAILY

1. General inspection pertinent to all machinery includes paying particular attention to any abnormal noise. Check lubrication if noise is apparent.
2. If backwash system fitted, give high pressure wash for short period.
3. Check head loss, drum or rake speed, backwash pressure in relation to water quality. Make any necessary adjustments.
4. Check wash water jet nozzles for blockage.
5. In the case of microscreens, check fabric condition as seen from wash water run down externally. If fabric is blinded (plugged), wash water will run down on both sides of the jets. If the fabric is clean, after its passage under the jets, run down will normally be only on the upcoming side.
6. In the case of coarse screens, check operation of cleaning mechanism or, if manual cleaning, rake screen as necessary.
7. Visual inspection of condition of screening media. Also look for objects lodged in screens and objects that could obstruct flow or movement of screens or cleaning mechanisms.

WEEKLY

1. Operate equipment through a complete cycle in manual and automatic modes.
2. Operate cleaning mechanism (backwash jets) at various settings.
3. Lubricate machinery.
4. If ultraviolet equipment is fitted (supplementary cleaning equipment), wipe reflector clean. Ultraviolet equipment is fitted on microscreens with stainless steel mesh to continuously condition the fabric and keep it free from slimes. Chlorine could be used to control the slimes, but also could be corrosive.
5. Check functioning of any other supplemental cleaning apparatus.

MONTHLY

1. Inspect all safety features of equipment including access walkways, guard rails, and manhole covers.
2. Check oil levels in drive units and fill as necessary.
3. Examine screening media for permanent blockage or mechanical defects. Repair or clean as necessary.

3 MONTHS

1. Check gasket materials including sealing bands and rubber wipers, if fitted. Repair or replace as necessary.
2. Check for wear on rubber brushes, if fitted, on drive units and replace where necessary.
3. Check tightness of all fasteners.

6 MONTHS

1. Check all suspension parts.
2. Check drive sprockets and chains for alignment and wear.
3. Drain oil from drive unit, flush and refill with proper lubrication.
4. Inspect main bearings and, if necessary, fill with specified grease.

12 MONTH MAINTENANCE

Clean all surfaces, paint as necessary, replace any worn or corroded parts. (Follow inspection check points included in manufacturer's instruction manual.)

Operator actions required. Wash dirty media with an acid or caustic solution depending on the media material and type of waste. If the media shows signs of wear or damage, it should be repaired or replaced. For this purpose it will be necessary to drain down machinery and proceed as described in the section (6.242) on corrective maintenance. The backwash system can usually be adjusted without draining down. Oil levels also can be checked and filled up as necessary while the equipment is in operation. Reports to the supervisor should be made regularly on the condition and performance of the equipment. These reports should preferably be in writing on printed forms which detail the complete maintenance schedule.

Repair or replace the screening media wherever holes develop; otherwise solids will pass into the downstream processes. Also, the condition of the screen will steadily deteriorate. Make sure the backwash system is functioning effectively; otherwise the screen will remain dirty and become progressively blocked, thus hindering flow. Unless the machinery is lubricated, it will eventually fail.

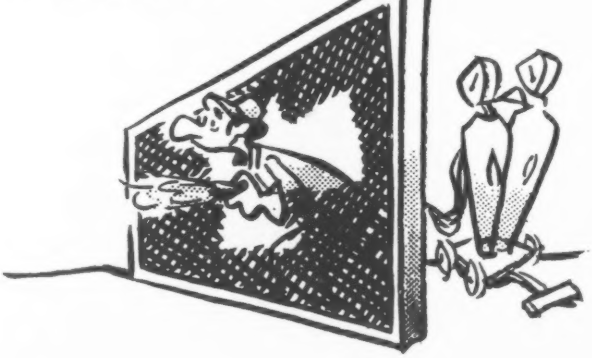
6.242 Corrective Maintenance

The straining or screening media usually needs the most attention, particularly if this is made of woven wire cloth since it can be broken by impingement of floating objects or by stress due to overloading from differential head and fatigue. Plates or bars are not so easily damaged.

To carry out a repair on the screen, the machinery should be stopped, isolated and drained down. Observe the usual safety procedures (Section 6.22, "Safety Procedure"). Wire mesh can be repaired in place by soldering or lapping in a new section. Sometimes a panel must be removed and replaced. If bars or plates do become damaged, removal and repair or replacement is usually required.

When there is a defect in the screening media, it is obvious by the passage of material that would normally be intercepted.

A defect in the machinery is usually shown by erratic uneven motion or unusual noise. The source of the trouble must be located by visual inspection and repair carried out as recommended in the manufacturer's manual. In most cleaning systems, sprays are self-cleaning or designed to avoid plugging from solids in the backwash water. Occasionally a jet will become jammed or obstructed and this is shown by the section of the screen beneath the faulty jet remaining dirty. The jet should be cleaned in place, if this is possible, or removed and cleaned, repaired or replaced.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 450.

6.2M List items that should be visually inspected every day that a screen is in operation.

6.2N How can a woven wire screening media be broken?

6.25 Review of Plans and Specifications

Points to watch for in reviewing plans and specifications are discussed in this section.

6.250 Concrete Channels and Chambers

Concrete channels and chambers should be designed to allow positive drainage. There should be isolating valves or sluice gates to allow individual chambers to be dewatered. The floor of the chamber should be made with a slope running towards the drain valve. Each separate chamber should have its own drainage valve. Remember that drains must run by gravity to the point of disposal. There should be no upward slope in these drain lines nor should there be any tendency for back pressure. If gravity disposal is not possible, a drainage sump may be provided with a dewatering pump. This pump should be of the "non-clog" design.

When reviewing the chamber work, try to be sure dirty water is prevented from bypassing the screen and finding its way to the suction of the backwash pump. This can interfere with operation of the pump. It can also lead to clogging of the spray jets if these are fitted on the screen or strainer. Since the screen or strainer will be of metallic construction, it is best to keep chlorine away from the unit or backwash pump to eliminate possible corrosion. In the case of microscreens, weirs are used inside the chambers to maintain the proper drum submergence and prevent excessive head differences.

Dimensions of the chambers should be checked before installing the screen. The positions of main parts such as the drive unit and control equipment should be identified. Make sure there is adequate working space around these parts. Also be sure guard rails are provided to prevent anyone falling into the chamber. Access walkways may be needed above the machinery if servicing of the equipment is required.

6.251 Design of Coarse Screens

The chief design features to consider when selecting screens are the area of the screen and size of mesh to deal with required flow and loading conditions. Manufacturers' literature gives capacity figures for their units, based on the mesh opening and application. These figures range from 60 to 200 gallons per minute per square foot (40 to 135 liters per sec per sq m) of submerged or effective area depending upon mesh size and loading expected.

A rule of thumb which provides a check on capacity is as follows:

1. Calculate the total effective submerged area which is the area of coarse screen exposed to flow of effluent. Then assume that the screen is half blocked with intercepted debris.
2. Calculate the available open area as total area × percent open area (mesh) × 50 percent (half blocked).
3. Take an arbitrary figure of one foot per second (0.3 m/sec) flow velocity. This will give available flow capacity in worst conditions of loading.

EXAMPLE

Known		**Unknown**
DRUM SCREEN		
Diameter, ft	= 7 ft 6 in	Flow velocity through screen, fps
Length, ft	= 5 ft	
Depth Submerged, ft	= 6 ft	
Portion blanked off by support structure	= 0.10 of submerged area	
Square mesh screen	= 10 wires/inch in each direction	
Percentage open area, %	= 58%	
Flow, GPM	= 8,400 GPM	
Portion of screen plugged	= 0.50	

1. Calculate the total submerged area of the screen. If the screen is 7 feet - 6 inches in diameter and is submerged to a depth of 6 feet, approximately 70.5 percent of the screen is submerged.

$$\begin{aligned}\text{Submerged Area, sq ft} &= \pi \times \text{Diameter, ft} \times \text{Length, ft} \times \text{Portion Submerged}\\ &= 3.1416 \times 7.5\text{ ft} \times 5\text{ ft} \times 0.705\\ &= 83.1\text{ sq ft}\end{aligned}$$

2. Assume the supporting structure blanks off 10 percent of the total submerged area. Calculate the net effective submerged area.

$$\begin{aligned}\text{Net submerged area, sq ft} &= \text{Submerged Area, sq ft} - \text{Supporting Structure Area, sq ft}\\ &= 83.1\text{ sq ft} - 0.10\,(83.1\text{ sq ft})\\ &= 75\text{ sq ft}\end{aligned}$$

3. If the drum is fitted with square mesh having 10 wires per inch each direction, a wire mesh handbook will reveal that 58 percent of the screen area is open area. Calculate the net effective submerged area available for flow through the screen.

$$\begin{aligned}\text{Net effective submerged area, sq ft} &= \text{Net submerged area, sq ft} \times \text{Portion open area}\\ &= 75\text{ sq ft} \times 0.58\\ &= 43.5\text{ sq ft}\end{aligned}$$

4. Calculate the flow of 8,400 gallons per minute to cubic feet per second.

$$\begin{aligned}\text{Flow, }\frac{\text{cu ft}}{\text{sec}} &= \text{Flow }\frac{\text{gal}}{\text{min}} \times \frac{1\text{ cu ft}}{7.48\text{ gal}} \times \frac{1\text{ min}}{60\text{ sec}}\\ &= 8400\ \frac{\text{gal}}{\text{min}} \times \frac{1\text{ cu ft}}{7.48\text{ gal}} \times \frac{1\text{ min}}{60\text{ sec}}\\ &= 18.7\text{ cu ft/sec}\end{aligned}$$

5. Assume half of the net effective submerged area is plugged and the other half is not plugged. Determine the actual area for the wastewater being treated to flow through the screen.

$$\begin{aligned}\text{Area for flow, sq ft} &= \text{Net effective submerged area, sq ft} \times \text{Portion not plugged}\\ &= 43.5\text{ sq ft} \times 0.50\\ &= 21.75\text{ sq ft}\end{aligned}$$

6. Calculate the velocity of the water flowing through the screen.

$$\text{Velocity}, \frac{\text{ft}}{\text{sec}} = \frac{\text{Flow, cubic feet/sec}}{\text{Area, square feet}}$$

$$= \frac{18.7 \text{ cu ft/sec}}{21.75 \text{ sq ft}}$$

$$= 0.86 \text{ ft/sec}$$

Actual velocity should be at or below 1 ft/sec to prevent excessive head losses.

6.252 Design of Microscreens

Because the fabric used on microscreens is much finer than other types of screening units, blockage is more critical. Therefore a special formula has been developed as follows:

$$H = \frac{MQCf}{A} e^{NQ\, I/S}$$

Where H = head loss, inches

M = constant of 0.0267

Q = flow rate, GPM

A = submerged area

e = exponential constant, 2.718

N = constant of 0.1337

I = filterability index

S = drum speed, sq ft/min

Cf = mesh resistance to flow

= 1.7 for 23μ mesh

= 1.0 for 35μ mesh

= 0.8 for 60μ mesh

Using a head loss of three inches (7.5 cm), the capacity of a microscreen may be calculated from the above formula. Characteristics of the mesh and the effluent must be known to use the formula (see manufacturer's literature).

Flow capacity figures for microscreens are in the range 10 to 30 GPM per sq ft (6 to 20 liters per sec per sq m) of effective submerged area.

EXAMPLE

Known		**Unknown**
MICROSCREEN		
Flow, GPM	= 700 GPM	Head Loss through Screen in inches
Diameter, ft	= 7 ft 6 in	
Length, ft	= 5 ft	
Mesh Res., Cf	= 1.0	
Submerged Area, sq ft	= 75 sq ft	
Filterability Index, I	= 3.0	
Drum Speed of Rotation, ft/min	= 100 ft/min	

1. Determine filterability index, I, by running a sample of the water to be treated through the fabric on the screen. Typical values for wastewater range from 1 to 10 with higher values for waters with higher suspended solids.

2. Calculate S, the square feet of fabric entering the water each minute.

$$\text{Area S, sq ft/min} = \text{Speed of Rotation, ft/min} \times \text{Drum Length, ft}$$

$$= 100 \text{ ft/min} \times 5 \text{ ft}$$

$$= 500 \text{ sq ft/min}$$

3. Calculate the head loss through the screen in inches.

$$\text{H, in} = \frac{0.0267 \times \text{Q, GPM} \times \text{Cf}}{\text{A, sq ft}} \times e^{\frac{0.1337 \times \text{Q, GPM} \times 3.0}{\text{S, sq ft/min}}}$$

$$= \frac{0.267 \times 700 \text{ GPM} \times 1.0}{75 \text{ sq ft}} \times e^{\frac{0.1337 \times 700 \text{ GPM} \times 3.0}{500 \text{ sq ft/min}}}$$

$$= 2.492\, e^{0.56} \qquad e = 2.718$$

$$= 2.492\, (2.718)^{0.56}$$

$$= 2.492 \times 1.753$$

$$= 4.4 \text{ in}$$

Actual head loss should be at or below 3 inches for good design. To reduce the head loss on an existing screen, reduce the flow. If designing a facility to handle this flow, a larger screen area (A, sq ft) is needed.

6.253 Facilities Checklist

1. Check dimensions against manufacturers drawings of anchor bolts, structural, and hydraulic parts.
2. Check for access to all parts for servicing.
3. Check freedom of walk areas.
4. Check space around controls, safety features (rubber mats).
5. Check doors and other openings for possible removal of parts.
6. Check handrails and access walkways.
7. Check lifting facilities for heavy items.
8. Check servicing area alongside channels, non-slip surfaces or curbing.
9. Check that operating conditions will be suitable during bad weather conditions.
10. Check that there is adequate lighting, ventilation, and heating.
11. Examine possibility of danger from other adjacent processes including chlorine or other gaseous fumes. Consider possibility of flooding and noise levels from adjacent machinery.
12. Review design of equipment as to strength of parts, overall size, shape of channel admitting water to the screen, velocity in flowing channel, any recesses or hidden areas, inlet and outlet piping, gravity or pumped flow.
13. Briefly review overall design of equipment including adequate lubrication, bearings, gaskets and seals and accessibility for removal and servicing.
14. Check materials of construction for durability and strength and suitability for proposed duty, size of screen openings and strength of supports.

15. Check media design, size and strength.
16. Check for adequate cleaning facilities. Also determine how screenings will be disposed of.
17. Check source of backwash water which should be clean water (low or without solids) available for hose down; check chemicals or steam available for supplementary cleaning. Electric outlets should be located near points of need and should be of the proper voltage.
18. Check adequate drainage of floors, including basement and operating levels. These locations should be sloped to drain valves. Individual drain valves should be provided for each chamber.
19. Check to see if access ladders or foot rungs are available for manholes.
20. Check access to electrical wiring for removal purposes, circuit breakers, fuses, and control panels. Sufficient control features to enable equipment to be operated in manual automatic modes should be provided.
21. Check for adequate lighting of controls.
22. Check to see if equipment is near enough to controls to observe operation during start-up and shutdown.
23. There should be a safety switch on all electrical panels.
24. Check to see if isolating valves are provided to allow individual chambers to be drained down. Determine whether duplicate equipment or standby facilities and emergency bypasses are provided.
25. Check to see that all levers, valves and handles can be reached without difficulty from walkways and ladders.
26. Check to be sure that the machinery has adequate greasing and lubrication points.
27. Check whether safety equipment is available in the building, including protective clothing, gas mask, and life belts.
28. Check flow capacity of screens to insure adequate size for peak flow conditions and peak loading conditions.
29. Make sure there are no reverse slopes on piping. All piping must be self-draining with adequate valves, bends, and tees, and be properly supported and braced.
30. Floor stands should be provided for submerged valve operation.
31. Backwash pumps should have drowned or sumberged suctions.
32. Chemical feeders should be provided if necessary.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 450.

6.2O When reviewing plans and specifications, what items should be checked regarding concrete channels and chambers?

6.2P When reviewing plans and specifications, what items should be checked regarding electrical outlets?

6.26 Additional Reading

1. *MOP* 11, Chapter 6, "Screening."*
2. *TEXAS MANUAL*, Chapter 9, Screens.
3. *PROCESS DESIGN MANUAL FOR SUSPENDED SOLIDS REMOVAL*, Chapter 8, "Physical Straining Processes," Center for Environmental Research Information, U.S. Environmental Protection Agency, 26 West St. Clair Street, Cincinnati, Ohio 45268.
4. *PROCESS DESIGN MANUAL FOR UPGRADING EXISTING WASTEWATER TREATMENT PLANTS*, Chapter 7, "Effluent Polishing Techniques," Center for Environmental Research Information, U. S. Environmental Protection Agency, 26 West St. Clair Street, Cincinnati, Ohio 45268.
5. *WASTEWATER ENGINEERING: TREATMENT, DISPOSAL AND REUSE*, Volume I, Second Edition, Metcalf & Eddy, Inc., Chapter 12, "Advanced Wastewater Treatment," McGraw-Hill Book Company, College Division, 27th Floor, 1221 Avenue of the Americas, New York, New York 10020. Price. $51.95.
6. Manufacturers' literature and operating manuals.

* Depends on edition.

END OF LESSON 3 OF 6 LESSONS ON INDUSTRIAL WASTE TREATMENT

Please answer the discussion and review questions before continuing with Lesson 4.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 6 Lessons)

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

14. Compare the differences between screens and clarifiers in the removal of solids from wastewaters.
15. How are screenings disposed of from moving screens and microscreens?
16. Describe how a microscreen removes floatable solids and suspended particles from wastewater.
17. Identify high-risk activities or safety hazards that you might encounter when operating and maintaining screens or microscreens.
18. How would you determine if correct start-up procedures were used to start a microscreen?
19. What items should be considered when inspecting the screening media during normal operation?
20. What abnormal conditions might have to be handled when operating a screening process?
21. What information should be reported to your supervisor regarding a screening process?

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

(Lesson 4 of 6 Lessons)

6.3 NEUTRALIZATION[9] by Mark Acerra

6.30 Need for Neutralization

Industrial wastes usually contain acidic or alkaline (caustic) materials which required neutralization before biological treatment or discharge to receiving waters. The neutralization of water is measured in terms of pH. pH is measured on a scale from 0 to 14 with 7 being neutral. Levels below 7 are acidic and above 7 are caustic. In practice, industrial wastewaters are rarely truly "neutralized" to a pH of 7. They are adjusted to within an acceptable pH range. The range is determined by either the water quality criteria of the receiving stream, the waste treatment process being used, or the physical integrity of the wastewater collection system.

Water quality criteria are determined by the needs of the receiving body of water and are usually determined by the responsible state and federal regulatory agencies. Receiving water quality criteria are written into NPDES discharge permits under which the process discharges and are independent of the process being used to treat the wastewater. pH is an important factor in the chemical and biological systems of natural waters. For example, cyanide toxicity to fish increases as the pH is lowered. Ammonia has been shown to be 10 times as toxic at pH 8.0 than as at pH 7.0. The solubility of metal compounds contained in bottom sediments or as suspended material is affected by pH. The following pH ranges from "Quality Criteria of Water" have been adopted (July 1976) by the U.S. Environmental Protection Agency.

Range	Beneficial Water Uses
5-9	Domestic water supplies (welfare)
6.5-9.0	Freshwater aquatic life
6.5-8.5	Marine aquatic life

NPDES permits for discharges into receiving waters with these beneficial water uses require effluent pH values within these ranges. In addition to meeting the water quality criteria of the receiving stream, industrial wastewaters usually require treatment for specific pollutants such as oil, grease, metals, suspended solids, organic materials and other polluting compounds. The various waste treatment processes commonly used are pH dependent. These processes work or work best within a specific pH range. Some wastewater streams require several pH adjustments to accommodate process steps as well as final discharge to the receiving stream. When pH makes the difference in whether or not a process will work, pH control is critically important and must be continuously monitored. When pH determines the relative efficiency of a process, pH control is not critical if the use of excess treatment chemicals or longer mixing times are available. However, this will result in higher operating costs and decreased ability to handle process upsets.

Neutralization can also be important in corrosion control. Unpainted pieces of steel rusting in the presence of drinking water indicate a need for corrosion control. The rate of rusting or corrosion increases in rainwater and increases even more in saltwater. Concrete can be cleaned or washed with a muriatic acid (HCl) solution. Plastic or PVC pipes corrode when exposed to many solvents. Therefore the equipment and pipe in a treatment plant must be designed to handle the wastes being processed. The equipment and piping must be used as designed to prevent corrosion as a result of improper use. Also, ventilation must be adequate to keep the fumes from the processes from attacking the motors, switches, lights and other fixtures in buildings. If the pH of a solution is allowed to drift outside of the designed range, corrosion can start. Conversely, some processes require pH adjustment so that they can be discharged through an existing wastewater collection system.

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[9] *Neutralization (new-trall-i-ZAY-shun). Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.*

6.31 Basic Principles

When solutions of an acid and a metallic hydroxide or base are mixed in equivalent quantities, each exactly cancels the properties of the other. The process is called *NEUTRALIZATION*. The products are a salt and water. Evaporation of the water will reveal the salt in crystalline form. An acid neutralizes a hydroxide and a hydroxide neutralizes an acid.

pH is an indication of the strength or intensity of acid or basic conditions. The pH is an index of hydrogen ion activity and is used as an indication of acidity and alkalinity while not a measure of either.

A material which ionizes to form positively charged hydrogen ions is an acid:

$$\underset{\text{sulfuric acid}}{H_2SO_4} \rightarrow \underset{\text{hydrogen ions}}{2H^+} + \underset{\text{sulfate ion}}{SO_4^=}$$

A material which ionizes to form negatively charged hydroxyl ions is an alkali or base:

$$\underset{\text{sodium hydroxide}}{NaOH} \rightarrow \underset{\text{sodium ion}}{Na^+} + \underset{\text{hydroxyl ion}}{OH^-}$$

Pure water which ionized to a certain extent produces both hydrogen and hydroxyl ions in equal concentrations:

$$H_2O \rightarrow H^+ + OH^-$$

The degree to which ionization proceeds in pure water is the basis for the pH scale and is expressed as the ion product constant of water. From the law of chemical mass action it has been determined that the product of the hydrogen ion concentration and the hydroxyl ion concentration in water is equal to 1/100,000,000,000,000 or 10^{-14} with 10^{-7} hydrogen ions and 10^{-7} hydroxyl ions. pH is expressed as the negative common logarithm of the hydrogen ion concentration or

$$pH = \log \frac{1}{\{H^+\}}$$

The pH index ranges between 0 and 14 as shown in Table 6.2. pH values less than 7 are acidic and greater than 7 are basic.

The addition of a certain quantity of acid or alkali to some solutions will not only fail to produce an expected pH change, but in some cases will result in almost no pH change. Such a solution is said to be *BUFFERED*.[10] All mixtures of weak acids and their salts or weak bases and their salts are buffer mixtures. The total acidity or alkalinity often are used to estimate the buffer capacity of a solution.

TABLE 6.2 VALUES OF pH FOR VARIOUS SUBSTANCES[a]

	pH	Hydrogen Ion Concentration Mols/Liter	Hydroxyl Ion Concentration Mols/Liter	pH Common Household Items[b]		pH of Various Industrial Chemicals[c]
	0	1	0.00000000000001		0	← Sulfuric Acid 4.9% (1.0 *N*)
	1	0.1	0.0000000000001		1	← Hydrochloric Acid 0.37% (0.1 *N*) Sulfuric Acid 0.49% (0.1 *N*)
	2	0.01	0.000000000001	Lemon juice →	2	← Acetic Acid 0.6% (0.1 *N*)
	3	0.001	0.00000000001	Orange juice →	3	
Acidic	4	0.0001	0.0000000001	Beer →	4	
	5	0.00001	0.000000001	Cheese →	5	← Hydrocyanic Acid 0.27% (0.1 *N*)
	6	0.000001	0.00000001	Milk →	6	
Neutral →	7	0.0000001	0.0000001	Pure Water Egg White →	7	
	8	0.00000001	0.000001		8	← Sodium Bicarbonate 0.84% (0.1 *N*)
	9	0.000000001	0.00001	Borax →	9	← Potassium Acetate 0.98% (0.1 *N*)
	10	0.0000000001	0.0001	Milk of Magnesia →	10	← Ammonia 0.017% (0.01 *N*) Ammonia 1.7% (1.0 *N*)
Basic	11	0.00000000001	0.001		11	
	12	0.000000000001	0.01		12	← Caustic Soda 0.04% (0.01 *N*) ← Lime (Saturated Solution)
	13	0.0000000000001	0.1		13	← Caustic Soda 0.4% (0.1 *N*)
	14	0.00000000000001	1		14	← Caustic Soda 4% (1.0 *N*)

[a] Source: *THE INDUSTRIAL pH HANDBOOK* by Beckman Industries, Inc., 1963.
[b] Representative pH Values. pH of many food products may vary over considerable range.
[c] pH Values at 25°C. Values rounded off to nearest tenth.

---

[10] ***Buffer.*** *A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.*

Neutralization dynamics involve the changes caused in a solution when an acid mixes with a base. This neutralization involves the rate of change of pH, the equivalence point and the end points. In industrial wastewater, the flow being treated usually varies in strength and makeup. However,the chemistry involved is well known. Therefore, it is important that the operator understand the basic concepts involved and uses them as they apply to treating waste streams and treatment processes.

6.32 Chemistry

ALKALINITY[11] is the sum total of components in the water that tend to elevate the pH of the water above a value of about 4.5. Alkalinity is measured by titration with a standardized acid to a pH value of about 4.5 and it is expressed as mg/*L* $CaCO_3$ (calcium carbonate). Alkalinity is a measure of the buffering capacity of the water and may be defined as its capacity for neutralizing acid. The basic determination procedure is to take B ml of sample, add two drops of methyl orange indicator solution and titrate with standard sulfuric acid solution (.02 *N*) until the color changes from pink to orange.

$$\text{mg/}L \text{ alkalinity as } CaCO_3 = \frac{A \times 1000}{B}$$

A = ml standard acid used in titration

B = ml sample

ACIDITY[12] is also a capacity factor and may be defined as the capacity for neutralizing a base. Acidity is normally associated with the presence of carbon dioxide, mineral and organic acids, and salts of strong acids and weak bases. The basic determination procedure is to take B ml of sample, add two drops of methyl orange indicator and titrate with standard sodium hydroxide solution until color changes to faint orange.

$$\text{mg/}L \text{ acidity as } CaCO_3 = \frac{A \times 1000}{B}$$

A = ml standard sodium hydroxide used in titration

B = ml of sample

Freshwater suitable for aquatic life usually has an alkalinity of more than 20 mg/*L* and an acidity of zero.

Process water pH adjustment is achieved by adding available acid or alkaline substances. Alkaline substances commonly used are:

1. CaO (calcium oxide or lime), MgO (magnesium oxide), $Ca(OH)_2$ (calcium hydroxide, a hydrated form of lime) or $Mg(OH)_2$ (magnesium hydroxide), are the most commonly used chemicals because of availability, low cost and high capacity. Sludge bulk (volume) is major problem, but recovery is possible. Lime is either high calcium or dolomitic and comes either as quicklime or hydrated. It comes in dry form and is usually mixed with water before use. A solubility versus pH curve is shown in Figure 6.18 and the plotting data are in Table 6.3.
2. Sodium hydroxide (caustic soda). Sodium hydroxide (NaOH) is a convenient, controllable and commonly available chemical, but expensive. It is generally used for small or occasional applications or where limitation of sludge deposits is sought. Caustic soda is available in liquid form in two concentrations, 50 percent NaOH which begins to crystallize at 54°F (12°C) and 73 percent NaOH which begins to crystallize at 145°F (63°C). Therefore they must be properly stored and or diluted prior to use. Caustic soda is also available in an anhydrous or dry state (solid, flake, ground or powdered) at 100 percent concentration. In the dilution process, considerable heat is generated. Therefore the rate of dilution and method of cooling must be carefully controlled so that there is no boiling or splattering.

TABLE 6.3 pH OF CALCIUM HYDROXIDE SOLUTIONS AT 25°C

CaO gms per *L*	pH
0.064	11.27
0.065	11.28
0.122	11.54
0.164	11.66
0.271	11.89
0.462	12.10
0.680	12.29
0.710	12.31
0.975	12.44
1.027	12.47
1.160	12.53

Since solubility of lime decreases as the temperature decreases, the pH of lime solutions is correspondingly lower at lower temperatures.

Data from F. M. Lea and G. E. Bessey, Journal of the Chemical Society, p. 1612-1615 (1937).

The Alkali Conversion Table (Table 6.4) and Alkali Neutralization Graph (Figure 6.19) show the equivalent amounts of sodium hydroxide and the various forms of lime available that must be used to accomplish the same degree of neutralization. The Alkali Neutralization Graph shows the weighs of alkalis required to neutralize a given weight of any of the acids indicated.

Acid substances commonly used are:

1. Sulfuric acid (H_2SO_4) is the cheapest and most readily available. It is strongly corrosive, dense, oily, and colored clear or dark brown (depending on purity). Sulfuric acid should be of the USP (United States Pharmaceutical) grade free of heavy metals and is available in a number of grades containing 60 to 94 percent H_2SO_4. In the 93 percent grade, it is noncorrosive to steel drums, however, upon dilution it is highly corrosive.

---

[11] *Alkalinity (AL-ka-LIN-ity). The capacity of water or wastewater to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.*

[12] *Acidity. The capacity of water or wastewater to neutralize bases. Acidity is expressed in miligrams per liter of equivalent calcium carbonate. Acidity is not the same as pH because water does not have to be strongly acidic (low pH) to have a high acidity. Acidity is a measure of how much base can be added to a liquid without causing a great change in pH.*

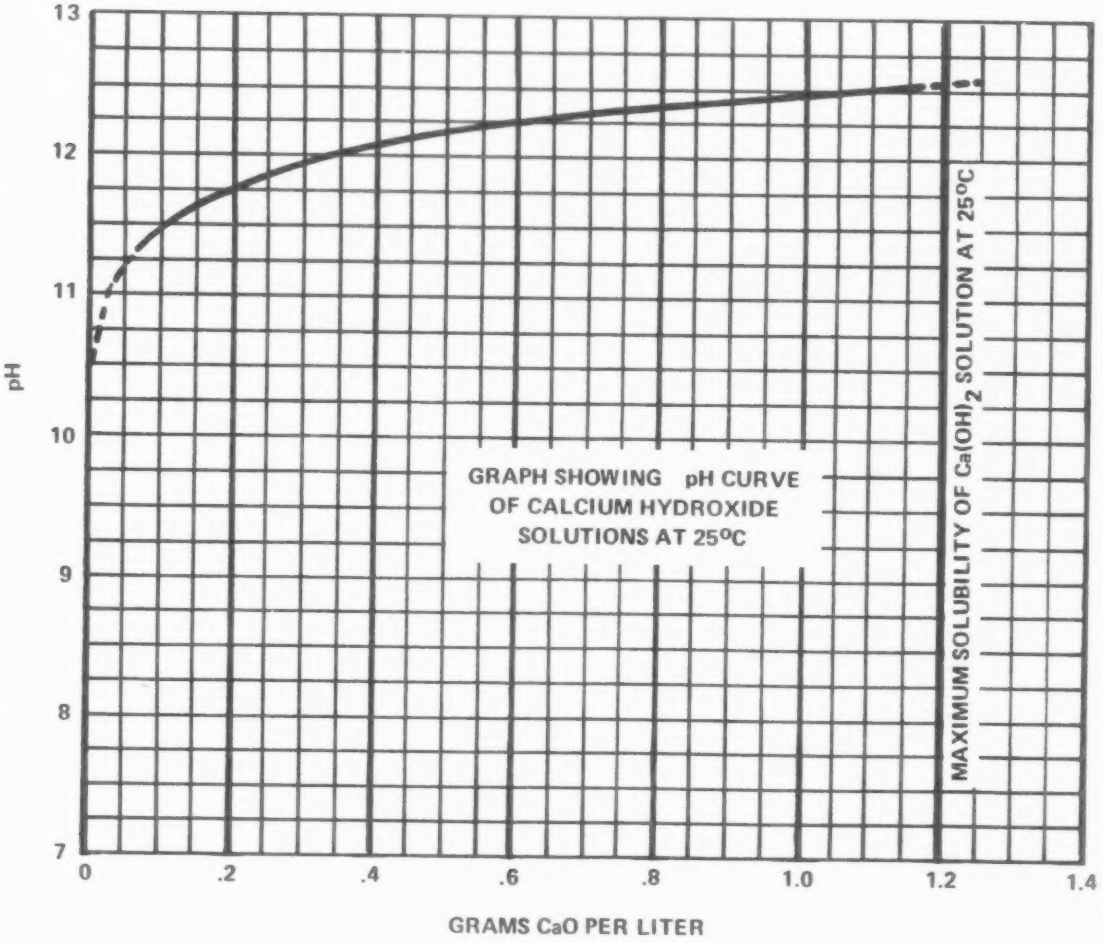

Fig. 6.18 Calcium hydroxide pH curve

(From *CHEMICAL LIME FACTS*, permission of National Lime Association, Washington, D.C., 1951)

TABLE 6.4 ALKALI CONVERSION TABLES[a]

NaOH	CaO	$Ca(OH)_2$	Ca - MgO	Na_2CO_3	Na_2CO_3	CaO	$Ca(OH)_2$	CaO - MgO	NaOH
1	.70	.93	.60	1.32	1	.53	.70	.45	.75
2	1.40	1.85	1.20	2.65	2	1.06	1.40	.91	1.51
3	2.10	2.78	1.81	3.97	3	1.59	2.10	1.36	2.26
4	2.80	3.70	2.41	5.30	4	2.12	2.80	1.82	3.02
5	3.50	4.63	3.01	6.62	5	2.65	3.49	2.27	3.77
6	4.21	5.56	3.61	7.95	6	3.17	4.19	2.73	4.53
7	4.91	6.48	4.22	9.27	7	3.70	4.89	3.18	5.28
8	5.61	7.41	4.82	10.60	8	4.23	5.59	3.64	6.04
9	6.31	8.33	5.42	11.92	9	4.76	6.29	4.09	6.79
10	7.01	9.26	6.02	13.25	10	5.29	6.99	4.55	7.55
15	10.51	13.89	9.04	19.87	15	7.94	10.48	6.82	11.32
20	14.02	18.52	12.05	26.50	20	10.58	13.98	9.09	15.10
25	17.52	23.15	15.06	33.12	25	13.23	17.47	11.37	18.87
30	21.03	27.78	18.07	39.75	30	15.87	20.97	13.64	22.64
35	24.53	32.41	21.08	46.37	35	18.52	24.46	15.91	26.42
40	28.04	37.04	24.10	53.00	40	21.16	27.96	18.19	30.19
45	31.54	41.67	27.11	59.62	45	23.81	31.45	20.46	33.97
50	35.05	46.30	30.12	66.24	50	26.45	34.95	22.73	37.74
55	38.55	50.93	33.13	72.87	55	29.10	38.44	25.01	41.51
60	42.05	55.57	36.15	79.49	60	31.74	41.94	27.28	45.29
65	44.56	60.20	39.16	86.12	65	34.39	45.43	29.56	49.06
70	49.06	64.83	42.17	92.74	70	37.03	48.93	31.83	52.83
75	52.57	69.46	45.18	99.37	75	39.68	52.42	34.10	56.61
80	56.07	74.09	48.19	105.99	80	42.32	55.92	36.38	60.38
85	59.58	78.72	51.21	112.62	85	44.97	59.41	38.65	64.16
90	63.08	83.35	54.22	119.24	90	47.61	62.91	40.92	67.93
95	66.59	87.98	57.23	125.86	95	50.26	66.40	43.20	71.70
100	70.09	92.61	60.24	132.49	100	52.90	69.90	45.47	75.48

[a] From *CHEMICAL LIME FACTS*, permission of National Lime Association, Washington, D.C., 1951.

2. Hydrochloric acid (HCl) or muriatric acid is a clear or slightly yellow, fuming, pungent liquid. It is poisonous and may contain iron or arsenic. Hydrochloric acid should be obtained in the purified form (U.S.P.) and is shipped in glass bottles, carboys, and rubber-lined steel drums, tank cars or trucks. It contains approximately 35 percent available hydrogen chloride. Fuming can be reduced by dilution to 20 percent HCl.

3. Where available CO_2 or SO_2 may be applied in gaseous form. Flue gases are accessible and economical for neutralization of alkaline waters in certain industries.

When mixed with water, acids and bases produce solutions made up wholly or partially of ions. Solutes that exist almost completely as ions in solution are termed strong *ELECTROLYTES.*[13] Those that react incompletely with the water so that both neutral molecules and ions formed from them are present are called weak electrolytes. The degree of ionization may be determined by measuring the electrical conductivity.

Chemical equilibrium exists when the reactants are forming as rapidly as the products, so that the composition of the mixture remains constant and does not change with time. At any one temperature, the equilibrium constant K has a fixed numerical value characteristic of the particular chemical equation. However, in industrial wastewater treatment, the stream being treated is made up of water plus many contaminants which provide competing equilibria. Furthermore, reaction rate, temperature and mixing conditions vary as does the waste loading. Therefore, the pure chemistry involved is not directly used by the operator in day-to-day activities.

As the graphic representation of pH versus added titrant, the titration curve provides a means to characterize the substance to be pH adjusted or neutralized and the amount of adjusting agent required. Titration curves for process optimization commonly are based on chemicals likely to be used in the process in a manner designed to indicate process variables such as contact time, temperature, nature and amount of solids, and handling characteristics in relation to the system pH.

The following titration curves illustrate terminology, characteristics, and changes with respect to a few commonly encountered adjustments. Figure 6.20 illustrates titration of a strong base (NaOH) with a strong acid (H_2SO_4). Initial additions of the titrant have a minor effect upon pH because NaOH plus product N_2SO_4 has little buffer capacity. The curve is almost flat for each addition of titrant prior to the inflection. The inflection indicates an approach to the equivalence point. The equivalence point is graphically located halfway along the straight line on the graph between the upper and lower inflections. Strong acid and base equivalence points commonly occur near pH 7.0. The product of volume and concentration of added titrant at the equivalence point is an estimate of sample basicity.

Figure 6.21 shows the effect of adding 4 percent or 1 *N* NaOH to a sample of industrial wastewater made up primarily of contact cooling water, machining rinse waters and miscellaneous combined process discharges. From the curve, the operator can readily determine the amount of caustic needed to adjust the pH to whatever value best suits the process used.

Figure 6.21 also shows the effect of adding 4.9 percent or 1 *N* H_2SO_4 to the same sample of industrial wastewater. The curves in Figures 6.20 and 6.21 differ significantly but provide the same basic information. Five gallons of 4 percent NaOH in 1,000 gallons of wastewater will result in a pH of 11.65, and 5 gallons of 4.9 percent H_2SO_4 in the same 1,000 gallons of wastewater will result in a pH of 3.0.

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[13] *Electrolyte (ELECT-tro-LIGHT). A substance which dissociates (separates) into two or more ions when it is dissolved in water.*

ALKALI NEUTRALIZATION GRAPH

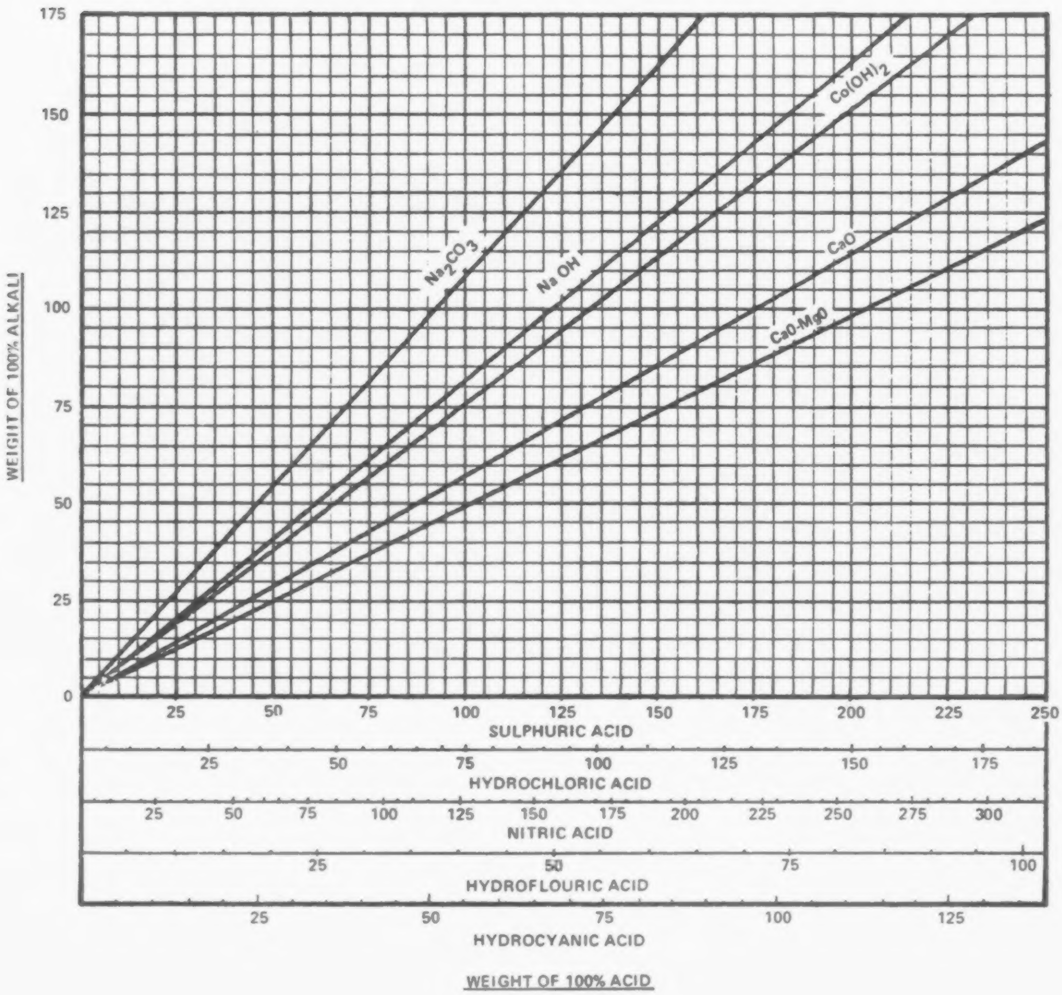


Fig. 6.19 Alkali neutralization graph

(From *CHEMICAL LIME FACTS*, permission of National Lime Association, Washington, D.C. 1951)

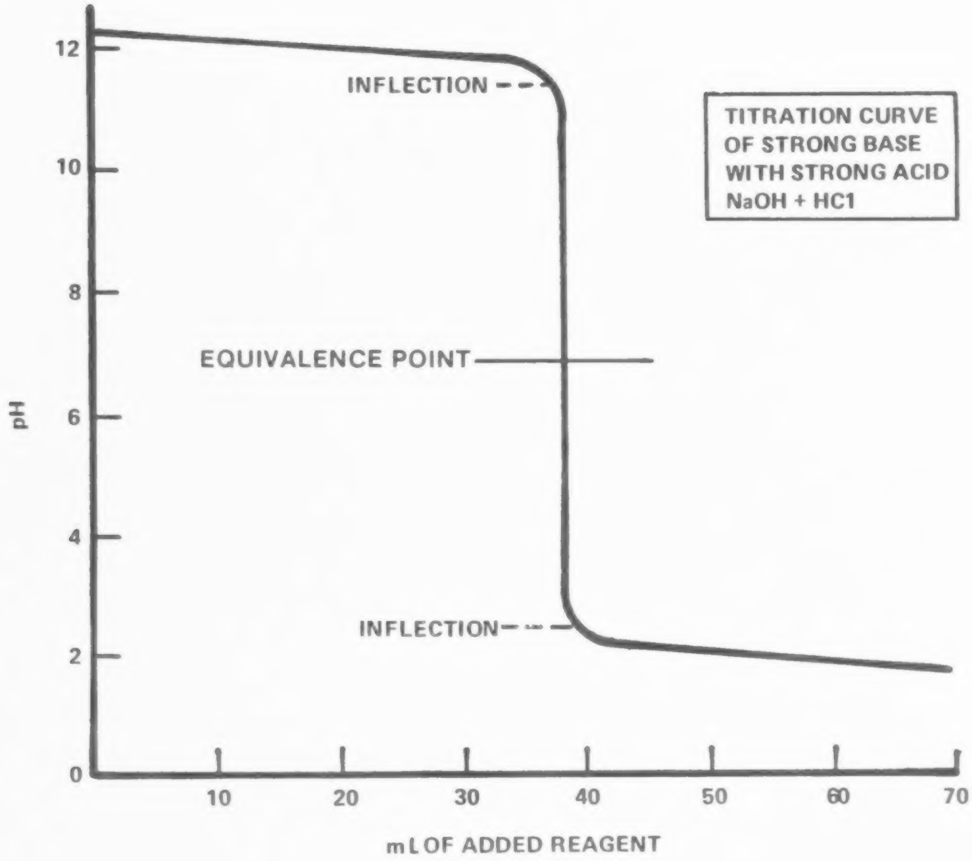


Fig. 6.20 Titration curve

(From *PHYSICAL CHEMICAL TREATMENT TECHNOLOGY*, U.S. Environmental Protection Agency, Washington, D.C., 1972)

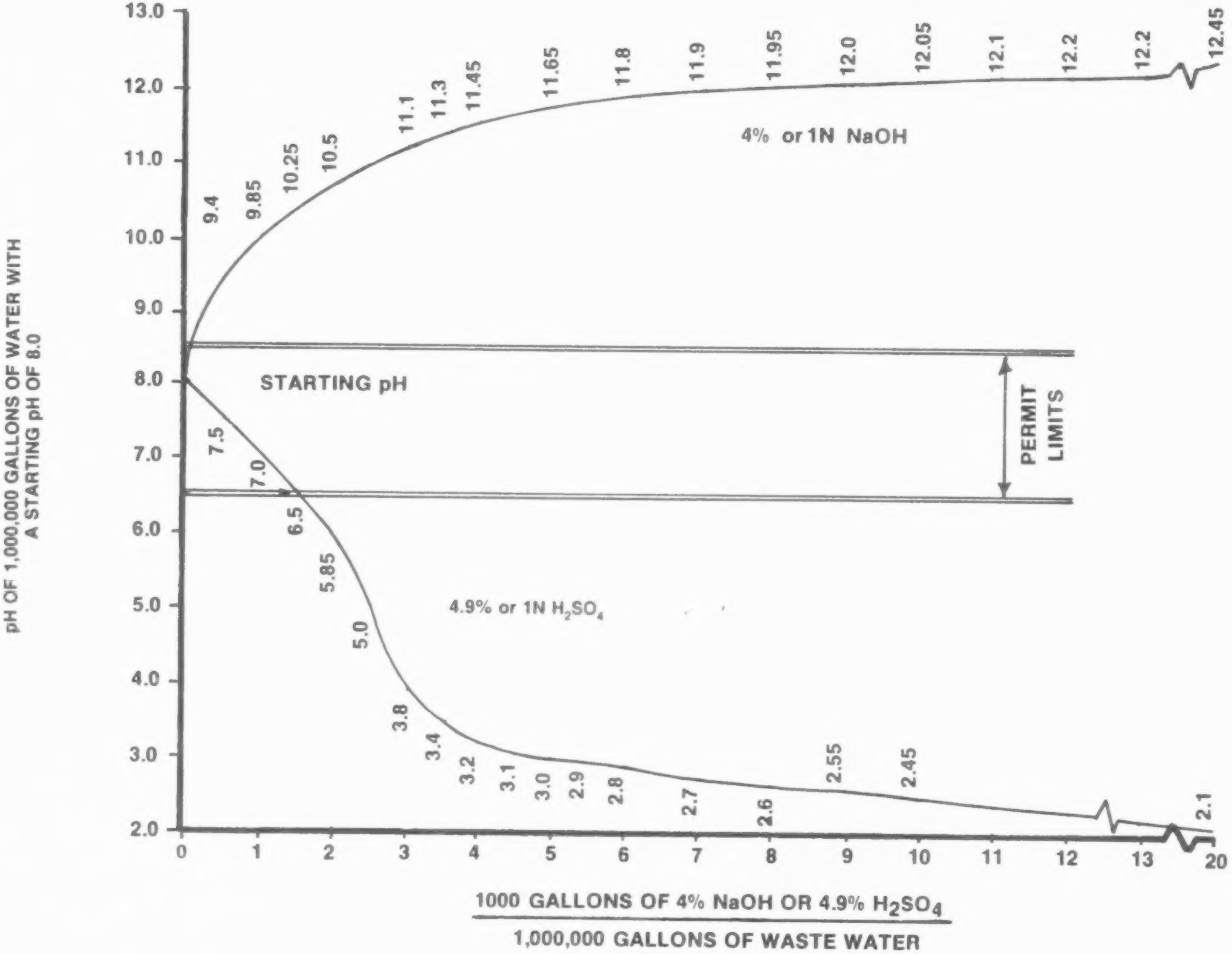


Fig. 6.21 Example titration of an industrial wastewater

Similar curves can and should be developed by the operator as a means of understanding any waste that must be neutralized. They are of further use in monitoring processes and calibrating automatic instrumentation. The steepness of the curves near the equivalence points is a good indication of the difficulty of pH control, especially when mixing times are short, tankage is too small, titrant concentrations are too high and feed equipment including pumps as well as instrumentation are marginally sized.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 450 and 451.

6.3A How does pH affect the rate of corrosion?

6.3B What is pH?

6.3C What is alkalinity?

6.3D To treat the same water, which would produce the most sludge, lime or caustic soda?

6.3E When diluting caustic soda, what items should be considered?

6.3F What is a titration curve?

6.33 Processes Requiring pH Adjustment and Neutralization

Almost every wastewater treatment process used to treat industrial wastewaters involves pH adjustment and the final effluent usually requires neutralization. The need for an optimum pH may be determined by a chemical reaction being used (such as cyanide destruction), the manufacturer's specifications with respect to a piece of equipment (such as to protect a reverse osmosis membrane), or by a physical process (such as coagulation of wastewater and sludge). An industrial wastewater treatment facility may receive streams separated as acid and alkaline or separated by pollutant. Process dynamics and economics often dictate preliminary treatment of each stream, including pH adjustment. The streams are then combined for additional treatment including pH adjustment and neutralization. A few of the more commonly encountered processes requiring pH control will be discussed in this section.

6.330 Precipitation of Metal Salts

Metal finishing such as iron pickling and copper plating involves the use of acids, caustics and chemicals. The wastewaters contain acids, alkaline cleaners, grease and oil, and heavy metals such as chromium, zinc, copper, iron, nickel, tin

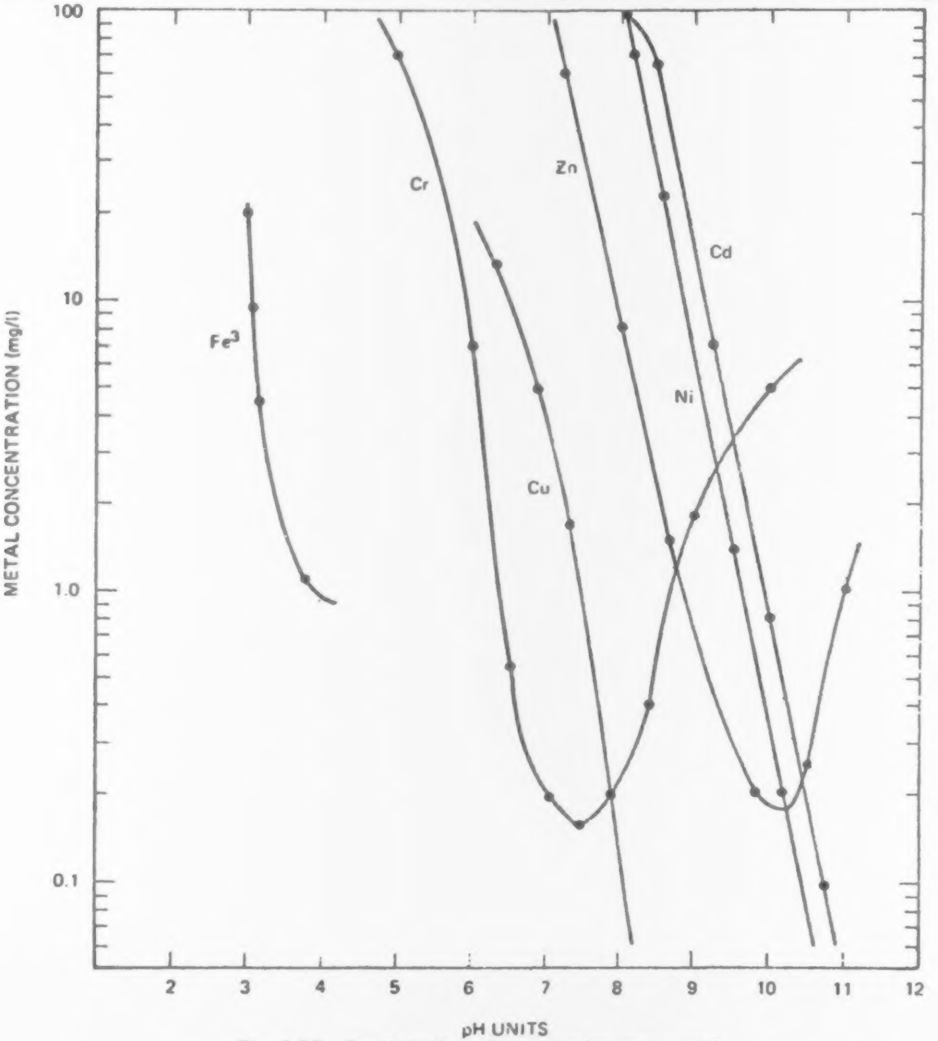


Fig. 6.22 Precipitation of metal salts versus pH

(From *METAL FINISHING WASTES*, EPA Technology Transfer, U. S. Environmental Protection Agency, Washington, D. C.)

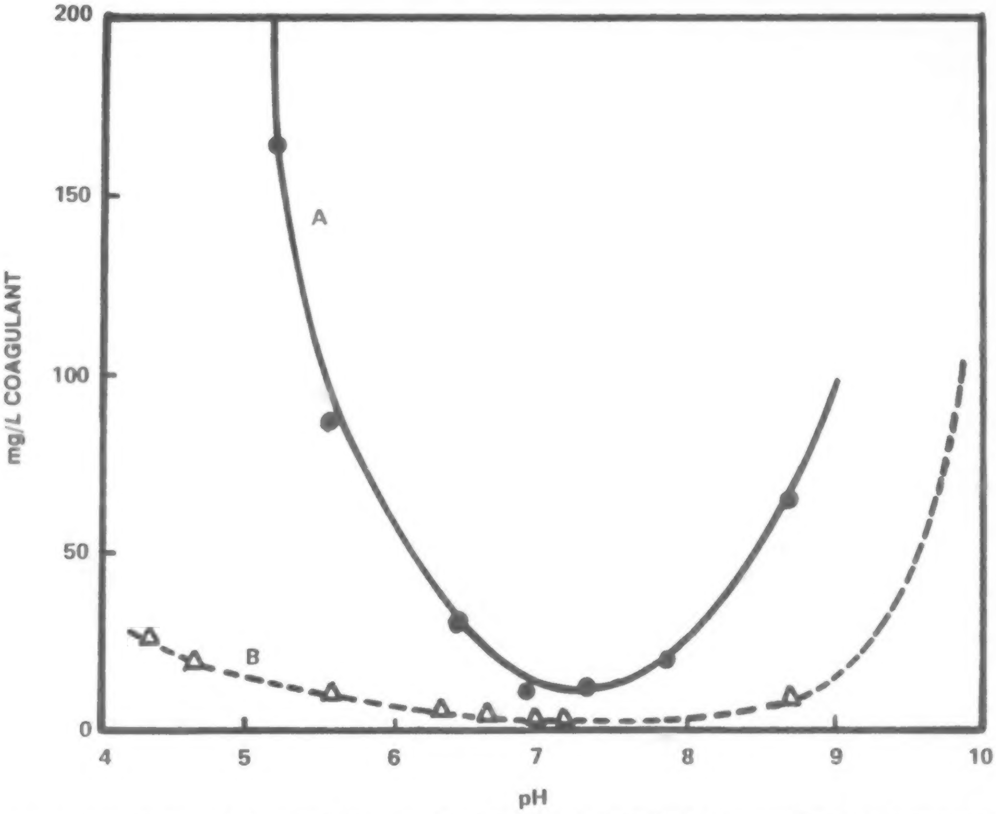


Fig. 6.23 Coagulation of 50 mg/L kaolin with aluminum sulfate and ferric sulfate. Comparison of pH zones of coagulation of clay turbidity by aluminum sulfate, curve A, and ferric sulfate, curve B. Points on the curves represent the coagulant dosage required to reduce clay turbidity to one-half its original value.

(Adapted from R. F. Packham, Proc. Soc. Water Treat. Exam., 12:15 (1963).)

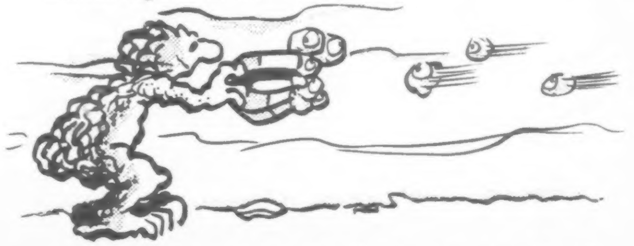
and cyanide. The waste streams come from one or more rinse tanks as well as the area sump. Metal salts tend to become insoluble in the neutral pH range, but not all metals will precipitate on neutralization. Metals also precipitate to different degrees at different pH values.

Figure 6.22 shows the solubility versus pH curves of various metals commonly encountered in metal finishing wastes. With mixed waste streams, the best pH for the most complete separation will be that which limits the content of the most toxic of the metal salts and for which the regulator limits are most stringent. With single salt streams, the optimum pH can be selected. As a rule for mixed streams, a pH from 8.0 to 8.5 is better (although not truly neutral) than is a pH closer to 7.0. If a pH outside of the 6.5 to 8.5 range is used, the final effluent will usually require neutralization prior to discharge.

Neutralization of metal pickling and plating wastes appears to be a rather unsophisticated chemical process. In practice, operating experience has shown that what is a relatively simple bench scale process in a beaker is a complicated and sophisticated control problem when applied to a continuously flowing stream which varies in flow rate, free acid or caustic content and various metal salt concentrations.

6.331 Coagulation[14] and Flocculation[15]

pH is considered to be the single most important variable in the coagulation process. Jar testing as well as full-scale operation have clearly shown that there is at least one pH range for any given water or wastewater within which good coagulation and flocculation occurs in the shortest time with a given coagulant dose. The pH range is affected by the chemical composition of the wastewater and types of coagulant and coagulant aids used as well as by the concentrations. Alum or aluminum sulfate — $Al_2(SO_4)_3 \cdot 18\ H_2O$, ferric chloride — $FeCl_3$ and ferric sulfate — $Fe_2(SO_4)_3$ are the most commonly used coagulants. Although alum is cheaper, more readily available and easier to handle, iron salts have the advantage of offering good coagulation over a broader pH range. This is most important where wastewater streams vary significantly in pH and pH control does not exist. Figure 6.23 shows the coagulation of 50 mg/liter of kaolin (a fine white clay used in the manufacture of porcelain with aluminum sulfate and ferric sulfate). Points on the curve represent the coagulant dosage required to reduce clay turbidity to one half its original value.



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[14] *Coagulation (co-AGG-you-LAY-shun). The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.*

[15] *Flocculation (FLOCK-you-LAY-shun). The gathering together of fine particles to form larger particles.*

Figure 6.24 shows phosphorus removal relative to alum dosage with almost zero phosphorus remaining at an alum dosage of 400 mg/*L*. However, the addition of alum also lowers the wastewater pH from above 7 to below 4. Before discharge to a receiving body of water, neutralization will be required. This shows that a chemical process sometimes will affect the wastewater pH even though pH adjustment was not needed. The amount of pH change is dependent on the buffering capacity of the wastestream.

6.332 Other Processes

Commonly used methods of wastewater treatment such as biological, reverse osmosis, ozonation, carbon adsorption, and ultrafiltration are either pH dependent or have a net affect on wastewater pH. Ultrafiltration is a membrane process used for the removal of organic compounds in an aqueous (watery) solution. The process usually operates at relatively low pressures of 100 to 1,000 kilonewtons per square meter (1 to 10 kg/sq cm or 14.5 to 145 psi). Efficiency can be measured in terms of the amount of dissolved solids or organic materials rejected by the membrane as well as by the clarity of the *SOLUTE*[16] when turbidity is an indicator (Figure 6.25).

Figures 6.26 and 6.27 show the dependence of rejection characteristics on pH and effect of pH on the optical density of the aqueous solutions. These curves are taken from a study done on the treatment of TNT manufacturing waste. The chemistry of the organic compounds at a high pH is suitable for membrane use. At a neutral or low pH, membrane technology is inappropriate. This type of technology is expensive but efficient and appropriate where other methods do not exist, water reuse is desired, or solute or concentrated waste disposal is of concern.

6.333 Sludge Conditioning and Disposal

Sludge treatment and dewatering is part of the industrial wastewater treatment process. Sludges are often classified by their basic chemical composition, pH, specific resistance and cake solids.

Specific resistance is an index of sludge filterability. Polymers are often used in the dewatering of sludge. Figures 6.28, 6.29, and 6.30 show the relationships between specific resistance (r), pH, polymer dosage (mg/*L*) and pH for nonionic, anionic and cationic polymers for a particular sludge. Figure 6.31 shows optimal polymer dosages versus pH for a particular sludge.

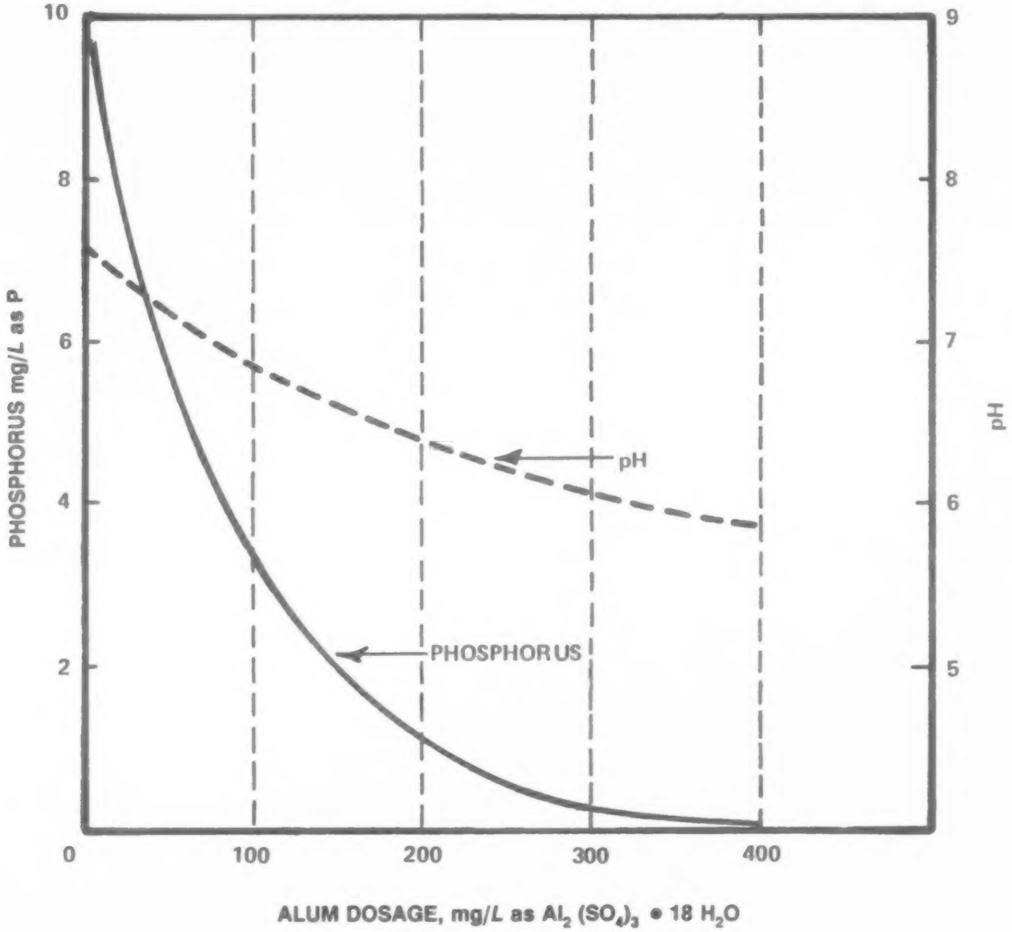

Fig. 6.24 Alum coagulation of wastewater

(From *HANDBOOK OF ADVANCED WASTEWATER TREATMENT*, 2nd Edition by Russell L. Culp, George M. Wesner and Gordon C. Culp, (C) 1978 by Litton Educational Publishing, Inc. Reprinted by permission of Van Nostrand Reinhold)

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[16] *Solute. The substance dissolved in a solution. A solution is made up of the solvent and the solute.*

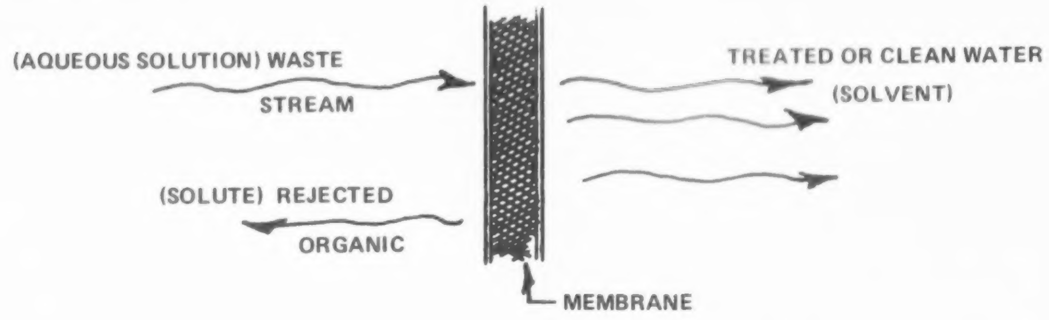

(AQUEOUS SOLUTION) WASTE
STREAM
TREATED OR CLEAN WATER
(SOLVENT)
(SOLUTE) REJECTED
ORGANIC
MEMBRANE

Fig. 6.25 Ultrafiltration process

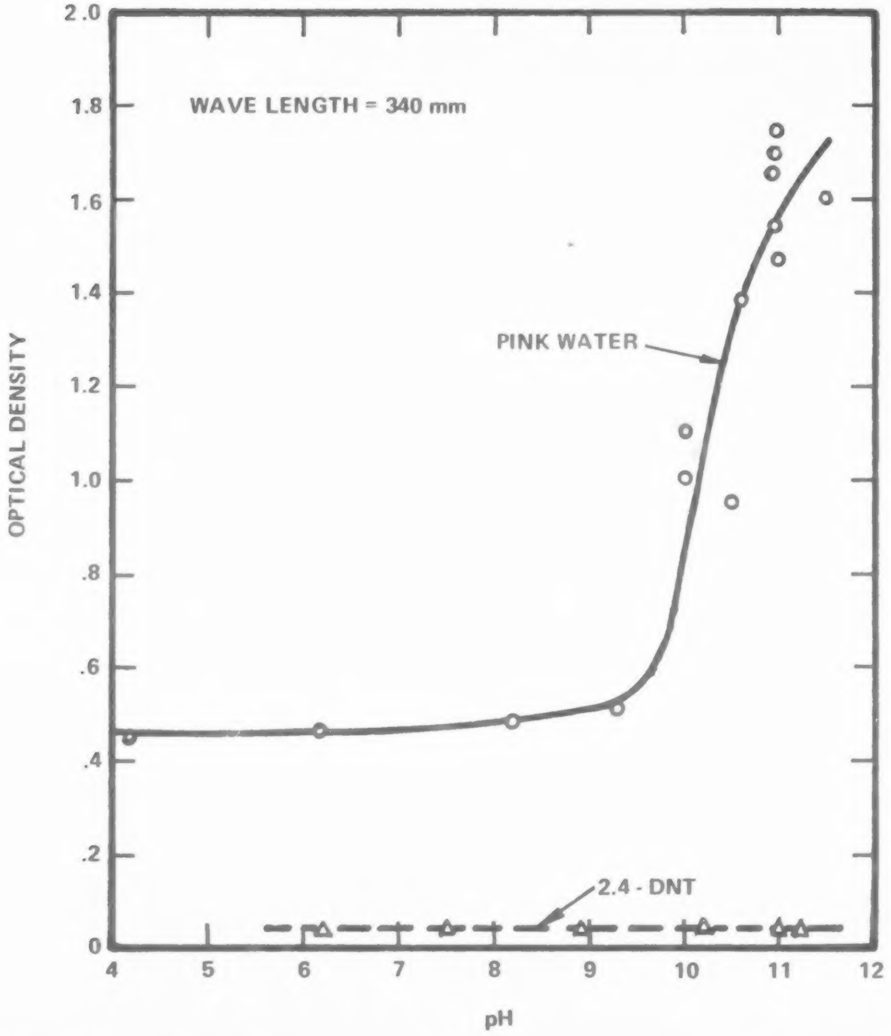


Fig. 6.26 Effect of pH on the optical density of actual pink water and of 2, 4-DNT solution

(From "Membrane Ultrafiltration for Treatment and Water Reuse of TNT — Manufacturing Wastes," by Bhattacharyya, Garrison, and Grieves. JWPCF, May 1977, 803, permission of Water Pollution Control Federation)

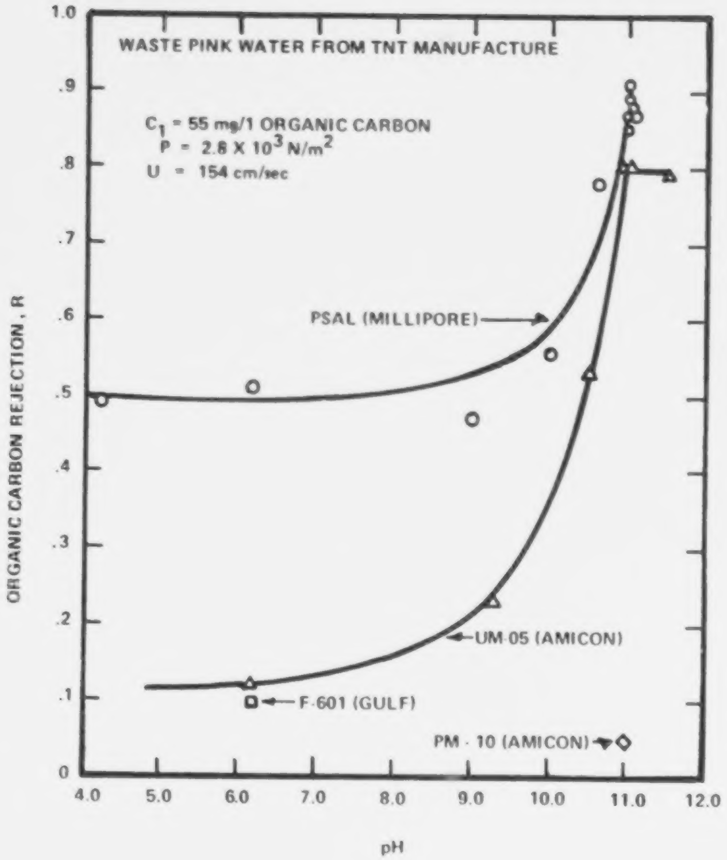


Fig. 6.27 Dependence of rejection characteristics of ultrafiltration membranes of pH

(From "Membrane Ultrafiltration for Treatment and Water Reuse of TNT — Manufacturing Wastes," by Bhattacharyya, Garrison, and Grieves. JWPCF, May 1977, 803, permission of Water Pollution Control Federation)

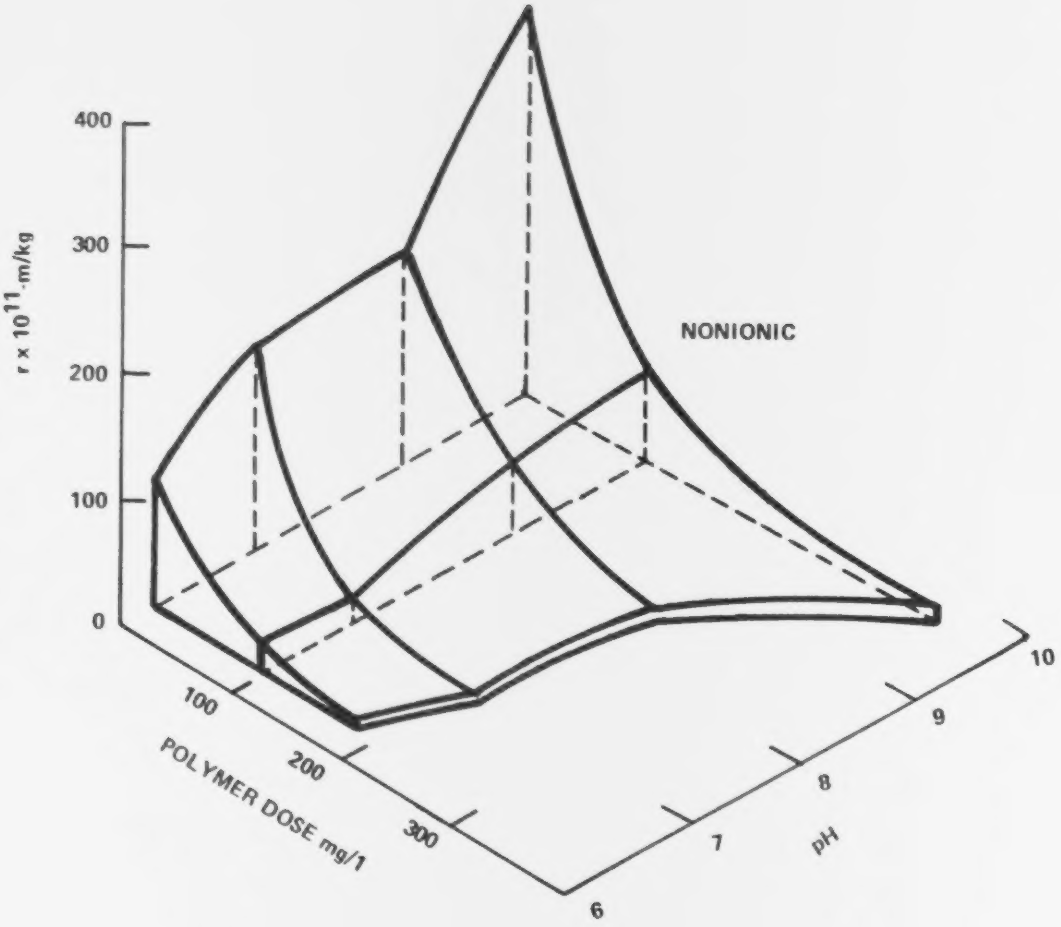


Fig. 6.28 Relationship among sludge specific resistance, pH, and dose with 15 × 10^{6} mol wt nonionic polymer

(From "Effects of pH and Mixing on Polymer Conditioning of Chemical Sludge," by O'Brien and Novak. Reprinted from the Journal American Water Works Association, *69*, by permission of the Association. Copyighted 1977 by the American Water Works Association, 666 West Quincy Avenue, Denver, Colorado 80235.)

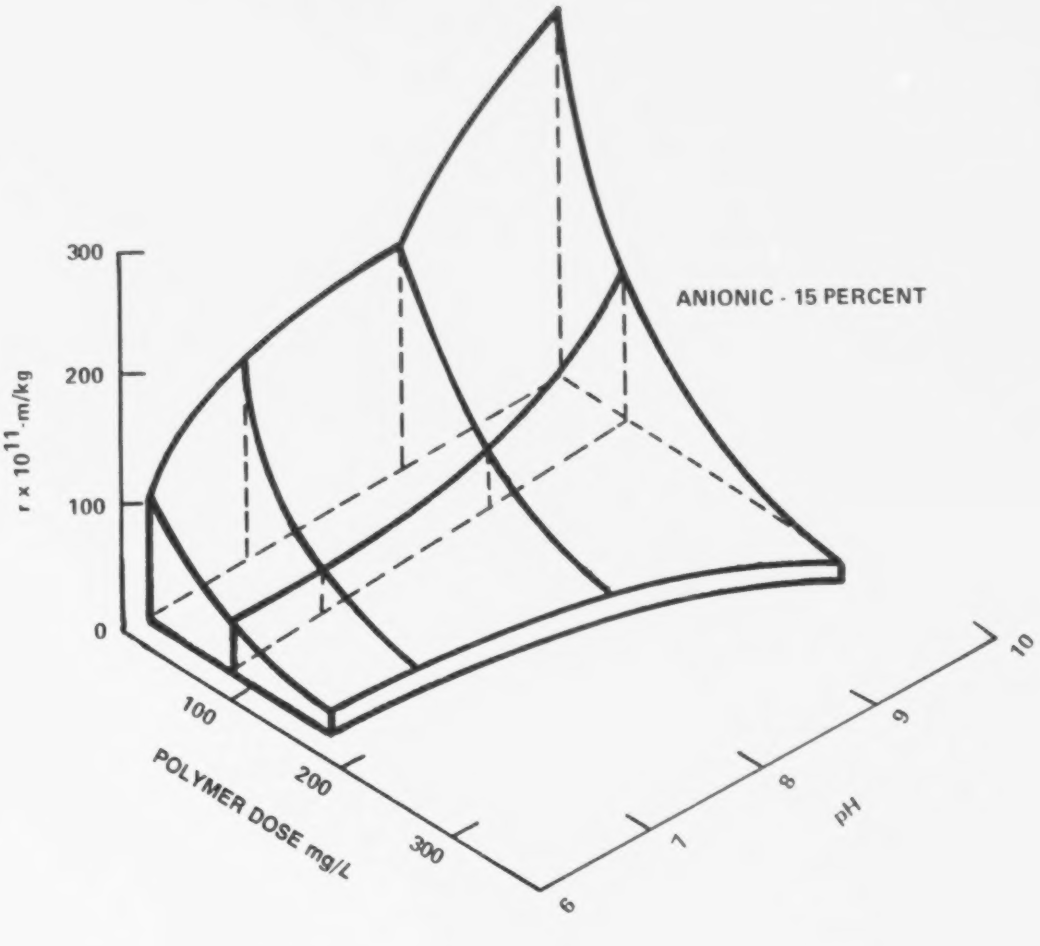


Fig. 6.29 Relationship among sludge specific resistance, pH, and dosage with 15 × 10^6 mol wt, 15 percent hydrolysis anionic polymer

(From "Effects of pH and Mixing on Polymer Conditioning of Chemical Sludge," by O'Brien and Novak. Reprinted from the Journal American Water Works Association, *69*, by permission of the Association. Copyrighted 1977 by the American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.)

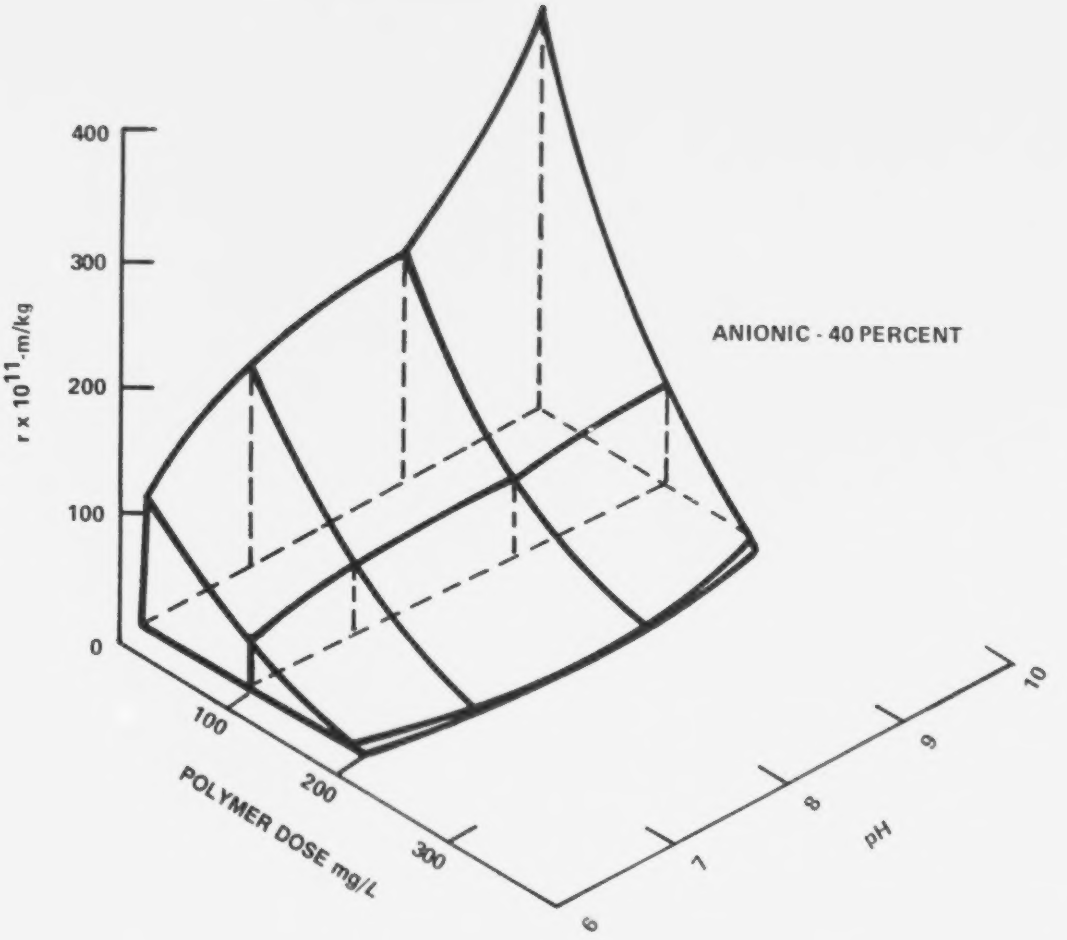


Fig. 6.30 Relationship among sludge specific resistance, pH, and dose with 15 × 10^6 mol wt, 40 percent hydrolysis anionic polymer

(From "Effects of pH and Mixing on Polymer Conditioning of Chemical Sludge," by O'Brien and Novak. Reprinted from the Journal American Water Works Association, *69*, by permission of the Association. Copyrighted 1977 by the American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.)

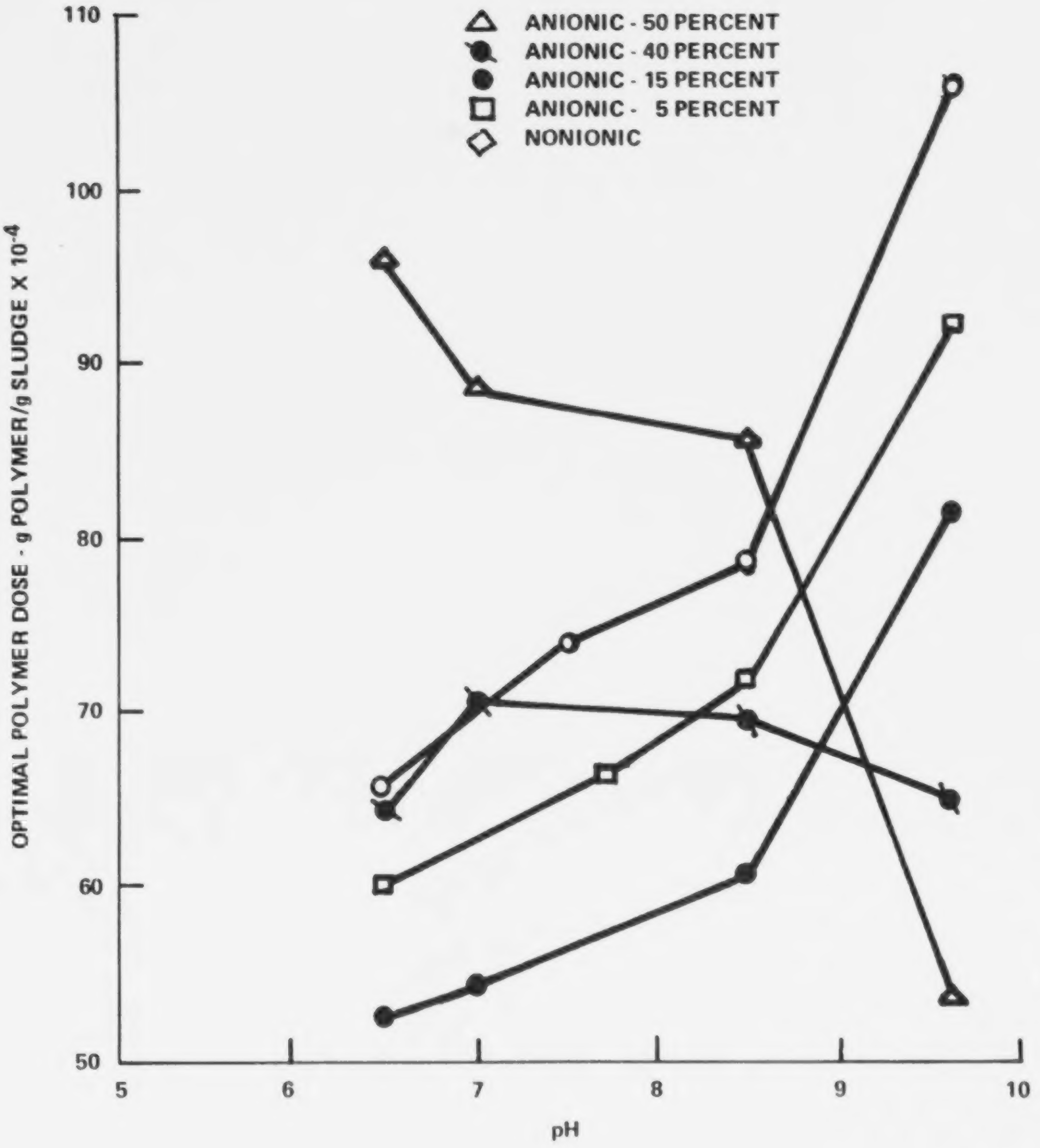


Fig. 6.31 Optimal polymer dose on sludge as a function of pH

(From "Effects of pH and Mixing on Polymer Conditioning of Chemical Sludge," by O'Brien and Novak. Reprinted from the Journal American Water Works Association, *69*, by permission of the Association. Copyrighted 1977 by the American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235.)

6.334 Summary

pH is an important consideration either as a control technique or as an after-effect in almost every wastewater treatment process, regardless of whether the source is industrial or sanitary or both. The expected effects for each process are known, but the actual effect must be determined by jar testing and pilot work before process system design. During start-up and operation the process used, including pH adjustment and neutralization, will require fine tuning. pH control is dependent upon temperature, mixing, control systems, and chemicals used, as well as the chemistry of neutralization.

ACID & ALKALI
ACID
ALKALI

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 451.

6.3G List the treatment processes that may require pH adjustment and neutralization.

6.3H List the most commonly used coagulants.

6.3I What is ultrafiltration?

6.3J How are sludges classified?

6.34 Process Mechanics

Industrial wastewater flows and strength of contaminants vary considerably by the day of the week, shift of day and time within each shift. Flows and strengths are production oriented as well as product dependent. In an old, large manufacturing facility, the waste is likely to be diluted with other process flows including cooling water and possibly sanitary waste. In a small or new manufacturing facility, the waste is likely to be an isolated highly contaminated stream, but with relatively little volume. All these factors have a direct bearing on the process mechanics. Treatment is either:

1. Batch or continuous,
2. Automatic or manually controlled,
3. Single or multiple stage,
4. Feed forward or feed back, and
5. Acid and alkali or just acid or just alkali.

Batch means that the waste is collected in a tank, pH adjusted and then allowed to reenter the wastewater stream. Each batch can be checked at the end of adjustment and so either manual or automatic control, or both, is applicable.

Continuous means that the flow never stops; therefore, the pH adjustment must be made during the amount of time a slug of waste is in the tank. Manual control is not practical, especially if flow and pH of wastewater vary significantly.

Automatic controlling uses automatic instrumentation to control chemical addition, control valving and to signal process upset.

Manual controlling uses laboratory instruments and tests to determine the state of the process. The operator uses nomographs and judgment to control chemical addition to determine when proper pH adjustment has been achieved.

Single stage has one point of adjustment. This is adequate for adjustment to within a range, where mixing is more than sufficient and where the waste stream is constant in direction and amount of chemical needed.

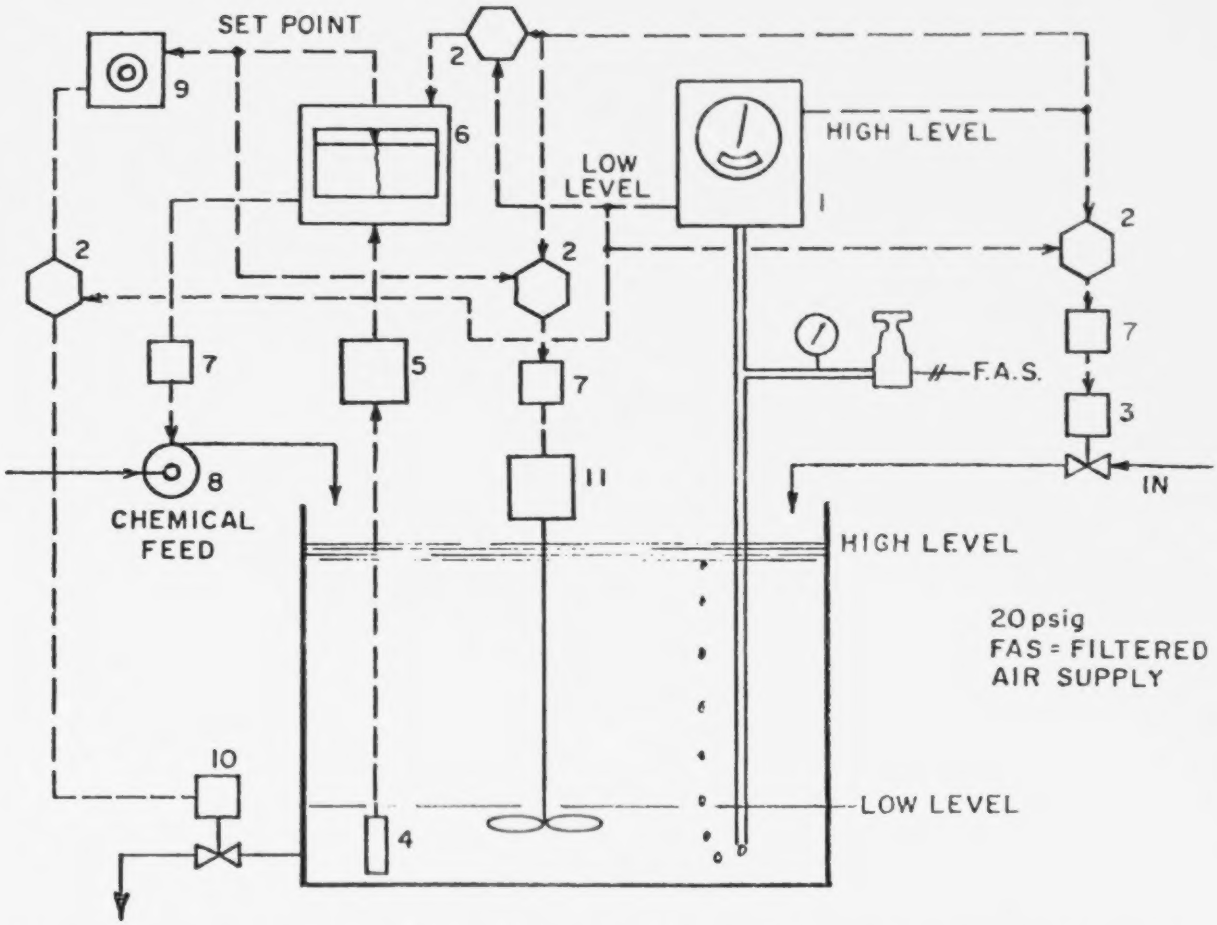
Multiple stage has two or more points of adjustment and is necessary where adjustment to one or more pH points is required, where mixing and tank size are small or multiple and where the waste stream requires varying amounts of acid and alkali.

Feed forward systems sense the pH and add the necessary chemicals downstream from the point of sensing. Due to time lag, the slug of wastewater being sensed is not the same as the slug being adjusted.

Feed back systems sense the pH and add the necessary chemical upstream from the point of sensing. Here the treated wastewater is re-sensed. Both feed systems require good mixing, especially in tanks as opposed to in pipelines. Quality of instrument(s) and placement of sensor(s) is critical.

Acid/alkali processes can make the necessary pH adjustment from a pH either below or above the desired pH. Therefore both acid and base can be chemically fed.

Acid or alkali means that the pH adjustment is made from only one direction. Two process loop diagrams shown in Figures 6.32 and 6.33 illustrate two of the many combinations available. These graphically indicate the important role played by the instrumentation. The operator should become thoroughly familiar with the operation and maintenance procedures contained in the manufacturer's literature. The operator also must be capable of manually determining pH by using electrometric measurement (a lab meter) and special indicator paper (litmus or pHydrion paper). Typical test procedures for acidity, alkalinity and pH are outlined in Chapter 16, "Laboratory Procedures and Chemistry," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS.*



1. Bubble-Type Indicating Level Controller. 2. Relay. 3. Water Inlet Valve. 4. pH Sensor. 5. pH Amplifier. 6. pH Recorder/Controller. 7. Manual-Off-Automatic Switch. 8. Chemical Feed Pump or Feed System. 9. Timer. 10. Drain Valve. 11. Agitator Drive.

Fig. 6.32 Simple batch-type pH control. High level of water initiates batch treatment.

(Permission of Honeywell, Inc.)

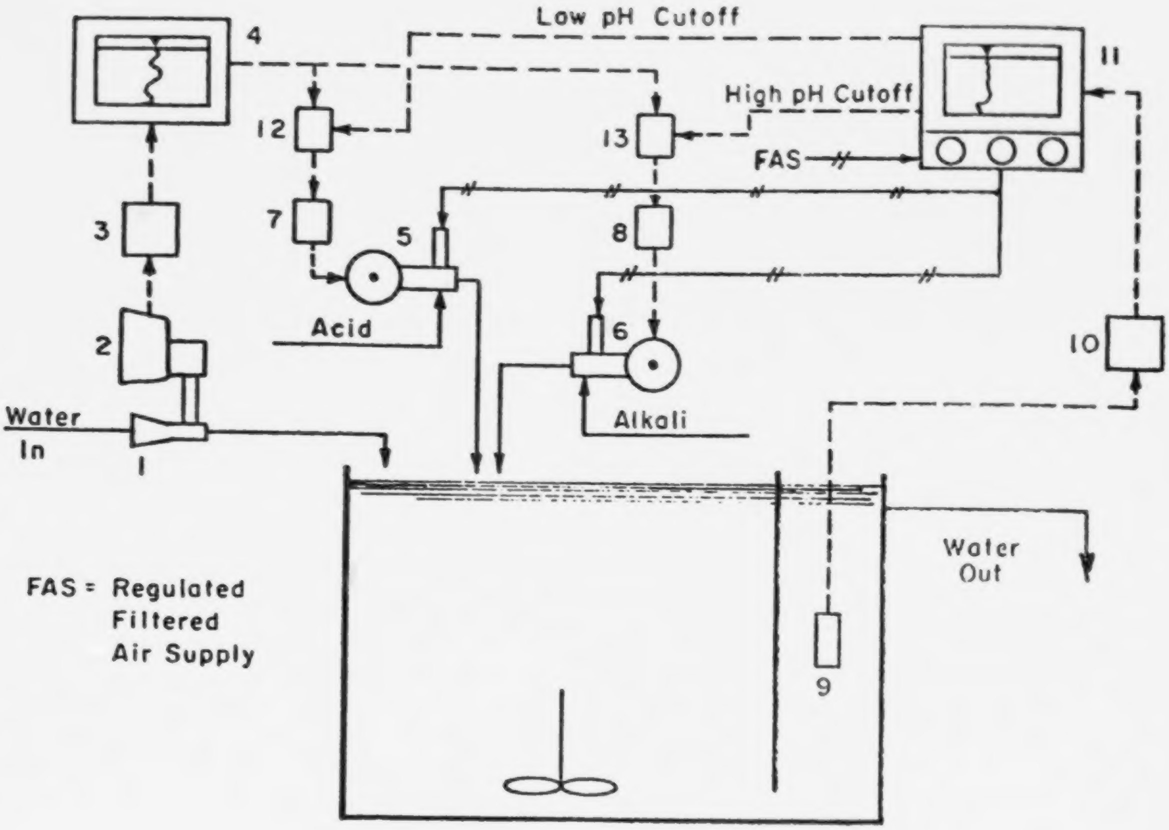
Figure 6.32 illustrates the simplest pH control system applicable to many industrial plants having either acid or alkaline streams that require pH adjustment and/or control.

DESCRIPTION OF OPERATION

Treatment tank fills with water to be treated. Level controller (1) senses when predetermined level (high) is reached. Relay (2) action in level control signal line closes water inlet valve (3), opens similar inlet valve on alternate treatment tank, energizes pH control system and starts the agitator. The pH sensor (4) senses pH of the water in the tank. The signal is amplified (5) and recorded by the pH recorder-controller (6). Chemical pump (8) introduces a neutralizing chemical until the desired set point is reached, when a backset or frontset switch on the recorder-controller shuts off chemical feed and energizes the timer (9). After the predetermined holding time has elapsed, the timer times out and relay (2) action opens the drain valve (10) to drain tank contents to service. When low water level is reached, relay action (2) stops the agitator, closes the drain valve and opens the inlet valve to start the next cycle. Manual-off-automatic switches (7) provide for remote manual pump operation, and inlet and drain valve actuation.

NOTE: Level control can be of the bubbler type (as illustrated), float type, electric conductance type, or any device that can provide a 115-volt signal when the tank is filled.

This system is suitable for adjusting pH of waters with or without suspended solids content.



1. Flow Tube. 2. Differential Pressure-to-Current (ΔP/I) Transmitter. 3. Square Root Extractor. 4. Flow Recorder/Controller. 5. Acid Pump with Pneumatic Stroke Adjustment. 6. Alkali Pump with Pneumatic Stroke Adjustment. 7, 8. Silicon Controlled Rectifier/(SCR) Controller. 9. pH Sensor. 10. pH Amplifier. 11. pH Recorder/Controller with Auto/Manual Switch. 12 and 13. Relays.

Fig. 6.33 Continuous neutralization of water proportional to pH and flow. Variable flow and high and/or low pH of water. Flow signal controls speed of acid and alkali pumps; pH of treated water controls the stroke on acid and alkali pumps.

(Permission of Honeywell, Inc.)

Many industrial process waters will fluctuate in terms of flow and many alternate between high and low pH values. The system described (see Figure 6.33) is capable of feeding either acid or alkali for neutralization proportional to pH and flow.

DESCRIPTION OF OPERATION

Flow is measured by a primary metering element (1) and differential pressure is sensed by a ΔP/I transmitter (2). The square root is extracted (3) and flow is recorded by the recorder-controller (4). A transmitting slidewire in the recorder is positioned proportional to flow and varies the speed of two chemical feed pumps (5 and 6) through individual SCR (silicon controlled rectifiers) controllers (7 and 8).

The pH of the water in the treatment tank is sensed (9) and the signal amplified (10), then recorded by a recorder-controller with automatic-manual switch (11). If pH is above the set point, i.e., alkaline, the pneumatic signal from the pH controller increases the stroke of the acid pump (5) equipped with pneumatic spring-to-decrease positioner. If the pH measurement is below set point, i.e., acidic, the pneumatic signal increases the stroke of the alkali pump (6) equipped with air-to-decrease, spring-to-increase pump stroke positioner.

Most chemical pumps will still deliver a minute quantity of chemical solution at zero stroke. For the sake of economy, therefore, it may be desirable to equip the recorder with backset switches and to provide relays (12, 13) to inhibit acid feed when pH is below a predetermined value and inhibit alkali feed when pH is above a set level.

6.35 Safety

Engineering control of hazards is the first step in the safety considerations at a treatment plant. The ability to contain and control spills can be designed into an existing or new facility. Equipment designed to handle the chemicals being used as well as in the environment created by the chemicals will need less maintenance and result in fewer injuries. Ventilation should be adequate to minimize chemical exposure to personnel. There should be no reason for skin, eye, nose or throat irritation. Electrical equipment should be designed to prevent deterioration or electrical shorting which can result from accumulations of chemicals on wiring and on terminals. Protective enclosures or splash walls should be used in critical exposure areas. Access to probes requiring periodic cleaning, calibration and replacement should be properly provided for.

The operator should:

1. Take part in drills regarding locations, purpose and use of emergency shutdown valves and switches.
2. Be knowledgeable (not just familiar) with the locations, purpose and use of personal protective equipment.
3. Be aware of the locations of and trained in the use of emergency shower and eye wash stations and other sources of water for use in emergencies.
4. Be keenly aware of all incompatible chemicals within or likely to be brought into the treatment plant site. If incompatible chemicals come in contact with each other, hazardous conditions could result, such as fires, explosions or toxic or corrosive atmospheres. A partial list is shown in Table 6.5.
5. Have sufficient and proper instructions on how to secure outside help during an emergency. This includes alerting fire, police and hospital officials as well as supervisory personnel.
6. Be provided with proper safety gear such as face shields, safety shoes, and breathing apparatus.
7. Be able to isolate and purge chemical lines prior to inspection and maintenance.
8. Be able to lock out and tag equipment during inspection and maintenance.
9. Have available and use formal procedures to start-up or take out of service systems, subsystems or units.

TABLE 6.5 PARTIAL LIST OF INCOMPATIBLE CHEMICALS[a]

Chemical	Prevent Contact With
Acetic acid	chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, and permanganates
Acetylene	chlorine, bromine, fluorine, copper, silver, and mercury
Alkaline metals (such as powdered aluminum or magnesium, sodium, and potassium)	carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, and halogens
Ammonia, anhydrous	mercury (such as in manometers), chlorine, calcium hypochlorite, iodine, bromine, and hydrofluoric acid anhydrous.
Ammonium nitrate	acids, metal powders, flammable liquids, chlorinate, nitrite, sulfur, and finely divided organic or combustible materials
Aniline	nitric acid and hydrogen peroxide
Bromine	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, and finely divided metals
Carbon, activated	calcium hypochlorite and all oxidizing agents
Chlorate	ammonium salts, acids, metal powders, sulfur, and finely divided organic or combustible materials
Chlorine	ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, and finely divided metals
Chlorine dioxide	ammonia, methane, phosphine, and hydrogen sulfide
Chromic acid	acetic acid, naphthalene, camphor, glycerine, turpentine, alcohol, and flammable liquids in general
Copper	acetylene and hydrogen peroxide
Cumene hydroperoxide	organic or inorganic acids
Flammable liquids	ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, and halogens
Fluorine	everything except special containers
Hydrocarbons (such as butane, propane, benzene, gasoline, and turpentine)	fluorine, chlorine, bromine, chromic acid, and sodium peroxide
Hydrocyanic acid	nitric acid and alkalies
Hydrofluoric acid, anhydrous	ammonia, aqueous or anhydrous
Hydrogen peroxide	copper, chromium, iron, most other metals and their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, and combustible materials
Hydrogen sulfide	fuming nitric acid and oxidizing gases
Iodine	acetylene, hydrogen, and ammonia (aqueous or anhydrous)
Mercury	acetylene, fulminic acid, and ammonia
Nitric acid, concentrated	acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, and flammable liquids and gases
Oxalic acid	silver and mercury
Perchloric acid	acetic anhydride, bismuth and its alloys, alcohol, paper, and wood
Potassium	carbon tetrachloride, carbon dioxide, and water
Potassium chlorate	sulfuric and other acids (see also chlorate)

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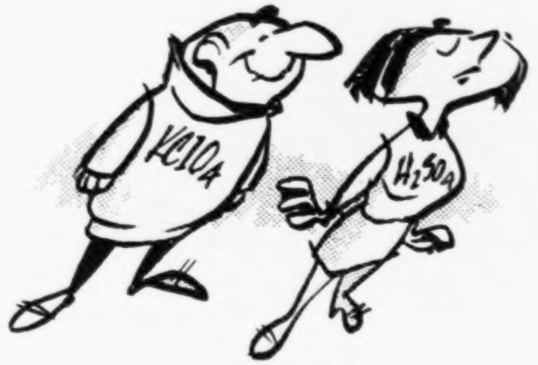
[a] Adapted from the *DANGEROUS CHEMICALS CODE*, Bureau of Fire Prevention, Los Angeles, California (1951).

Chemical	Prevent Contact With
Potassium perchlorate	sulfuric and other acids (see also chlorate)
Potassium permanganate	glycerine, ethylene glycol, benzaldehyde, and sulfuric acid
Silver	acetylene, oxalic acid, tartaric acid, fulminic acid, and ammonium compounds
Sodium	carbon tetrachloride, carbon dioxide, and water
Sodium peroxide	ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerine, ethylene glycol, ethyl acetate, methyl acetate, and furfural
Sulfuric acid	potassium chlorate, potassium perchlorate, and potassium permanganate (or similar compounds of such other light metals as sodium and lithium)



6.36 Construction Activities

Unfortunately, very few industries assign trained operators before or at the start of construction. An operator on the job costs industry money, especially with duration of construction often lasting longer than one year. But more significantly, trained industrial operators rarely exist. Whereas most municipal wastewater treatment plants are similar, industrial treatment plants vary dramatically from plant to plant. Therefore the operators receive on-the-job training, usually by the design engineers. The supervisor and some operators should be on the construction site during the period when major pieces of equipment are installed, piped up and wired. This period as well as start-up are critical periods for the operating staff. They can have a role as sidewalk superintendents, must prepare for start-up, and can (and should) perform unit checkout functions.

6.360 Sidewalk Superintendent

During construction, the drawings and specifications are part of the contract between the company and the contractor. Operators cannot tell a worker to make a walkway safer or to provide better access to a pH probe. But the operator can, through management, indicate unsafe areas, poor quality work and point out potential operating problems. An alert operator will walk into a room and ask questions such as:

1. Can I service and maintain the equipment safely?
2. Are switches and controls adequate and properly located?
3. Is lighting sufficient?
4. Is ventilation sufficient?
5. Is proper entrance to and exit from the room provided?
6. Are emergency alarms provided?

The operator can review plans and specs to see if the work being done is correct. If the answer to one of the above questions is no or if the work is wrong, the operator should make a constructive suggestion. The operator should also use this period to learn what the equipment looks like stripped down and bare, especially piping that will become buried, tanks that will be filled with water and gears and drives that will be enclosed.

6.361 Preparation for Start-Up

Months before unit check-out and start-up, the operators should be receiving classroom training in the processes to be used. They should be acting as sidewalk superintendents. Safety gear should be provided, explained and used including drills where applicable. An inventory of equipment, manuals and tools needed for start-up should be put together. Regular meetings should be held to discuss the status of the above and also to provide a forum for discussion. Design engineers should be available to answer questions. The operators should use this period to review start-up and operating manuals as they are being prepared. Key vendor representatives should be required to give training sessions.

6.362 Unit Check-Out and Start-Up

This phase refers to the "dry" checking of each piece of equipment and then the start-up of the system and placing it into normal operation. This is a period when the operators can develop step-by-step procedures. Examples for a simplified acid storage and feed system are shown in Tables 6.6, 6.7, 6.8, and 6.9. When operating experience is gained, these procedures can be modified and incorporated in an operation and maintenance manual. Formal procedures define areas of responsibility and significantly reduce the changes of errors and accidents.

6.37 Operation and Maintenance

Neutralization or pH adjustment systems consist of parts found in other locations of the treatment plant as well as the industrial site being served. Pumps are pumps and recorders are recorders. For the process to work, they must all function together as a system. The breakdown of one part will either shut the process down or necessitate manual operation. If certain parts are allowed to drift or to go out of calibration due to poor maintenance, process control will suffer. Because a chemical reaction is taking place and is usually being controlled by sensitive instrumentation, neutralization systems are trouble-prone and maintenance "hogs" (time consumers). An ounce of preventive maintenance is often worth a pound of breakdown maintenance. Points of particular concern are:

1. Primary sensors such as level probes and pH probes,
2. Chemical feed pump bearings and seals,
3. Chemical feed pump stroke controllers or positioners,
4. Automatic valves and limit switches,
5. Screw feeders or vibrators for dry chemicals, and
6. Mixers.

TABLE 6.6 TYPICAL CHECK-OUT PROCEDURE AND VERIFICATION

Item — Sulfuric Acid Storage Tanks (3)

Equipment Check-Out By

DESCRIPTION – Three horizontal fiberglass liquid sulfuric acid storage tanks of 9,000 gallons each. Each tank has a liquid level gage and tank number 3 has a high and low level alarm with an annunciator (noise alarm) on the main control panel.

CHECK-OUT

1. Tanks set in place and anchored with concrete placed in saddles.
2. All piping and valves in place and properly supported. Refer to drawing M21 and vendor drawing X-16. Four inch vent and overflow, 3 inch fill, six inch pump suction, 2 inch drain. Verify that feed line with outdoor gate valve and 3 inch quick connect and cap are installed.
3. Level alarm (hi and low) installed on tanks #1 and #3 wired to annunciator of main control panel (level alarm high and level alarm low).
   a. Verify that level switch 15 is at 4/5 full point. Refer to vendor sketch X-18.
   b. Verify that level switch 16 is at 1/5 full point.
   c. Verify that 115-volt power supply is connected to switches.
   d. Verify that angular rotation of floats initiates main control panel annunciator.

TABLE 6.7 TYPICAL CHECK-OUT PROCEDURE AND VERIFICATION

Item — Sulfuric Acid Transfer Pumps

Equipment Check-Out By

DESCRIPTION – Three Smith & Doe model 44-15 ½ HP pumps to transfer liquid sulfuric acid from storage tanks to dilution tee for feed to influent area of neutralization tanks.

1. Six-inch suction header in place with valves, pipe and calibration chamber, properly supported, expansion must be possible.
2. Verify that automatic valves function correctly (AV1, 2, 3).
   a. Check that 120-volt power is to valve motor.
   b. Verify that limit switches (open and closed) are wired properly and power supply is 120 volts.
3. Pump installed correctly, frame base bolted to slab and pump charged with lubricant.
4. Motor wired correctly 3 ϕ, 460 volts, fed through control panel from MCC #1, space G2 and power panel H1.
5. Sulfuric acid control panel installed and wired correctly from Panel H1. Refer to vendor drawing X-18 sheet 4.
6. Acid piping and dilution tee and piping to neutralization tank all in place and properly supported.
7. Rotameter FEI-10 installed. Four inch, 0-300 GPM. Verify that orifice plate for rotameter is installed in line.
8. Verify that calibration of rotameter is according to manufacturer's instructions.
9. Verify that feed rate positioner operates over entire range. Feed rate is a function of 4-20 ma from main control panel. Simulate signal and verify calibration stroke position.
10. Verify that back pressure valves are set at 50 psi, function at that setting, and verify inlet and outlet direction.
11. Verify that back pressure valve relief port is piped to appropriate drain.

TABLE 6.8 TYPICAL CHECK-OUT PROCEDURE AND VERIFICATION

Item — Sulfuric Acid Control Panel
(Refer to Smith & Doe drawing X-20 sheet 3)

Equipment Check-Out By

1. Verify that 4-20 ma signal from ratio station FY7 in main control panel to sulfuric acid control is connected at terminals 10 and 13.
2. Verify that Smith and Doe system check-out is complete and that 4-20 ma signal from FY7 is proportional to flow rates from 500 to 4,500 gallons per day. Refer to item 9 of metering pump section.
3. Verify pump running time meter control sequencing properly. Refer to Smith and Doe drawing X-20 sheet 4.

TABLE 6.9 TYPICAL CHECK-OUT PROCEDURE AND VERIFICATION

Equipment Check-Out By

1. Verify "as-built" drawings complete.
2. Verify all manufacturing drawings.
3. Verify maintenance and operating instructions complete.
4. Verify all spare parts "on hand" and correct.

Maintenance procedures should be set up and be as formal and detailed as practical. Most industrial sites are staffed to set up such programs. The operators should work with these people to see that a usable program is implemented. The treatment plant should maintain a complete set of drawings (up-dated) and equipment manuals. Operating logs showing all aspects of process, system and equipment operation should be maintained.

Troubleshooting is another important part of O&M. What do you do when the process is balky or does not work at all? For instance, a pH recorder indicates 10.0 when a pH of 8.0 is desired. Adding acid makes no difference. The operator must divide and conquer the system by the process of elimination. A typical procedure is as follows:

Check process stream with portable pH meter.

I. Agrees with recorder

Therefore, suspect acid feed system — check acid feed pump

1. Pump running normally — check acid supply

      a. Acid supply adequate and changing — check for leak
      b. Acid supply empty
      c. Acid supply adequate and not changing — check valving
   2. Pump running abnormally — check bearings
      — check motor and power supply
      — check pistons or impeller

II. Shows actual pH is less than 10.0

Therefore suspect instrumentation — check transmitter

   1. Transmitter okay — check primary sensor
      a. Sensor okay — check recorder
      b. Sensor bad — fix
      c. Sensor okay — check signal lines
   2. Transmitter bad — fix

III. Neither of the above routes work

Therefore look at interface between equipment and instrumentation controls:

   1. Signal being generated and received — suspect equipment
   2. Signal not being generated or received — suspect instruments
   3. Signal being generated and not received — suspect interface.

This was one of many cause and effect procedures that can be followed. Regular instrument calibration, if practiced, could have spotted a faulty sensor/indicator. Then the operator would have had a prime suspect. Routine equipment inspection could have uncovered an unusually noisy pump. Then the operator would have had a different prime suspect. Troubleshooting requires common sense as well as a good working knowledge of the process and its parts.

6.28 Instrumentation

Chapter 4, "Instrumentation," does an excellent job of showing the variety of industrial wastewater systems in terms of size and degree of sophistication. The chapter ties together some of the design considerations that must be adapted to the operating needs as well as the realities of the process.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 451.

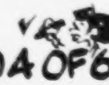
6.3K What is a batch process?

6.3L How can an operator manually determine pH?

6.3M Why should ventilation be provided in chemical feed facilities?

6.3N What kinds of questions should an alert operator consider when walking into a room under construction?

6.3O Why should formal procedures be developed for start-up, operation and shutdown of equipment and processes?



END OF LESSON 4 OF 6 LESSONS ON INDUSTRIAL WASTE TREATMENT

Please work the discussion and review questions before continuing.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 4 of 6 Lessons)

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 3.

22. Why is ventilation important in chemical storage areas?
23. What is a buffered solution?
24. What is the influence of alum on pH?
25. pH control is dependent upon what factors?
26. What is the difference between automatic and manual controlling?
27. Why should the operator be aware of incompatible chemicals?

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

(Lesson 5 of 6 Lessons)

6.4 COAGULATION AND PRECIPITATION

by Paul Amodeo

6.40 Need for Coagulation and Precipitation

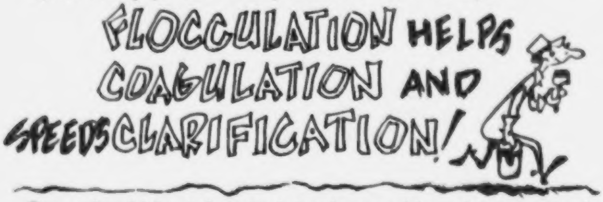
6.400 Purpose of Coagulation and Precipitation

Sedimentation can be defined in a broad sense as those operations performed in which a suspension of particles is separated into a clarified liquid and a more concentrated suspension. Sedimentation can be physically located downstream of any process in which such a suspension is generated (such as a biological treatment process) of it may be autonomous (by itself), representing the bulk of the treatment process of a plant. The latter is most common in the industrial waste treatment facilities in which metals and large quantities of suspended matter exist prior to any treatment. Most frequently, sufficient removal of suspensions is not economically accomplished by allowing the solids to settle at their own pace. Consequently, chemical coagulation is generally used to enhance the settling quality of the suspension, thereby decreasing the detention time required to achieve the desired liquid clarification. For the purpose of this section, chemical coagulation to enhance sedimentation will be primary concern.

6.401 Description of Process

Chemical coagulation involves the following operations:

1. Rapid Mix. In this operation, the suspension to be clarified is blended rapidly with the chemical coagulant to insure complete mixing.
2. Flocculation. The above liquid is agitated slowly to insure contact of coagulating chemicals with particles in suspension. Floc growth is accelerated by controlled particle collisions. Suspended particles gather together and form larger particles with higher settling velocities.
3. Clarification. The coagulated particles are allowed to settle quiescently (in still water) from the clarified liquid.



Care should be taken in interchangeably using the words flocculation and coagulation. Flocculation, as noted above, is the act of mixing and stirring the particles so as to insure adequate contact between suspended particles and the coagulating chemical. It is, therefore, the operation promoting coagulation. Coagulation is the actual gathering together of smaller suspended particles into flocs, thus forming a more readily settleable mass.

There are several different types of coagulating chemicals in use. Briefly, these may be classified into three broad categories dependent upon their mode of operation.

1. Electrostatic charge reducers.
2. Interparticle bridgers, and
3. Physical enmeshers.

Coagulating chemicals may be purchased in both solid and liquid form. Although typically, they have been mainly inorganic compounds, organic polymer technology is now advancing to the point where more economical and easier handling organic polymer substances are being used.

6.41 Principles of Coagulation

6.410 Physical Activities

Three separate operations are involved in the coagulation-precipitation process:

1. Rapid mix,
2. Flocculation, and
3. Precipitation (clarification or liquid-solids separation).

The initial process of rapid mix is important in two regards. First, it insures that there is a homogeneous mixture (complete mix) of suspended particles and coagulating chemicals. Secondly, it provides the initial incentive for particle contact. Characteristically, the rapid mix operation is of a short duration in relation to the operations following. Duration should be only that time necessary to provide a homogeneous mixture because too long a rapid mix may have an adverse effect upon coagulating due to the breaking up and separation of the forming floc. Therefore, the speed of the paddles becomes very important. Too rapid a speed may mechanically break up floc. Likewise, too slow a speed may not provide the needed mixing and may promote dead spots within the tank where mixing does not occur. Residence under these conditions may be increased for some particles and the settling of floc may occur before it can be effectively handled by removal equipment in the downstream processes.

Water with suspended matter is passed from the rapid mix to the flocculation tank. Paddle configuration (layout) and speed are such that the water and floc are encouraged to move slowly through the tank. Stirring during flocculation is for the purpose of promoting maximum contact between suspended particles. In doing so, particles gather together or coagulate to form a larger mass called floc. These aggregates or flocs of particles now have a greater overall density and can be more readily separated from the liquid portion.

As in the case of the rapid mix, two dangers must be avoided during flocculation. Paddle speed must be sufficient to maintain floc in suspension while at the same time it must not be so great as to shear and break up the floc formed.

Following flocculation, clarification occurs. During this operation, floc particles are allowed to settle out from the liquid portion, thereby accomplishing an effective separation. As such, precipitation is allowed to take place under somewhat quiescent (still water) conditions. The efficiency of the sedimentation process will be a function of the retention time, surface loading, the weir overflow rate and the solids loading. To some extent, also, in the initial portion of the operation, the process will be enhanced by the continuation of floc formation. As the large floc particles begin to settle, other particles still in suspension are attracted to the mass and settle out with it.

6.411 Destabilization Mechanisms

Suspended particles of interest for the coagulating operation fall within the size range of 1 to 2 microns. At this size, they possess natural stabilizing forces which prevent them from aggregating or gathering together. These forces include electrostatic repulsion which exists where the line polar charges on the particles will make them repell one another and physical separation from the surrounding media which may be effected by the formation of an adsorbed water layer on the particle. To bring about coagulation, not only must one disperse the particles to encourage contact, but one must also bring about a destabilizing mechanism. This is accomplished in one of three ways:

1. Electrostatic charge reduction,
2. Interparticle bridging, and
3. Physical enmeshment.

Electrostatic charge reduction takes advantage of the fact that many of the finely dispersed suspended particles in water possess a negative charge. By the addition of cationic metal salts (these have a positive charge), the negative charges become neutralized by absorption of the positive ion to the particle surface. With this mode of treatment, overdose of coagulant chemical should be avoided because this may include the reverse phenomenon in which there exists an excess of positive charges. In such a case, an anionic (negative charged) substance must be added to reestablish destabilization.

Polymers exist which have the capacity to adsorb to sites on suspended particles and act as a bridge between them (Fig. 6.34). In this way, effective aggregation can be enhanced. Overdose must again be avoided because the polymer may adsorb to all of the sites on a colloid without bridging, thereby bringing about restabilization. This mechanism is in effect when using non-ionic polymers or polymers with the same charge as the treated particles.

Physical enmeshment is accomplished by the hydrolysis products of iron, aluminum or at high pH, magnesium. Those cations will combine with hydroxyl ions (OH^-) found in water from its natural dissociation as shown below.

$H_2 \rightleftharpoons H^+ + OH^-$

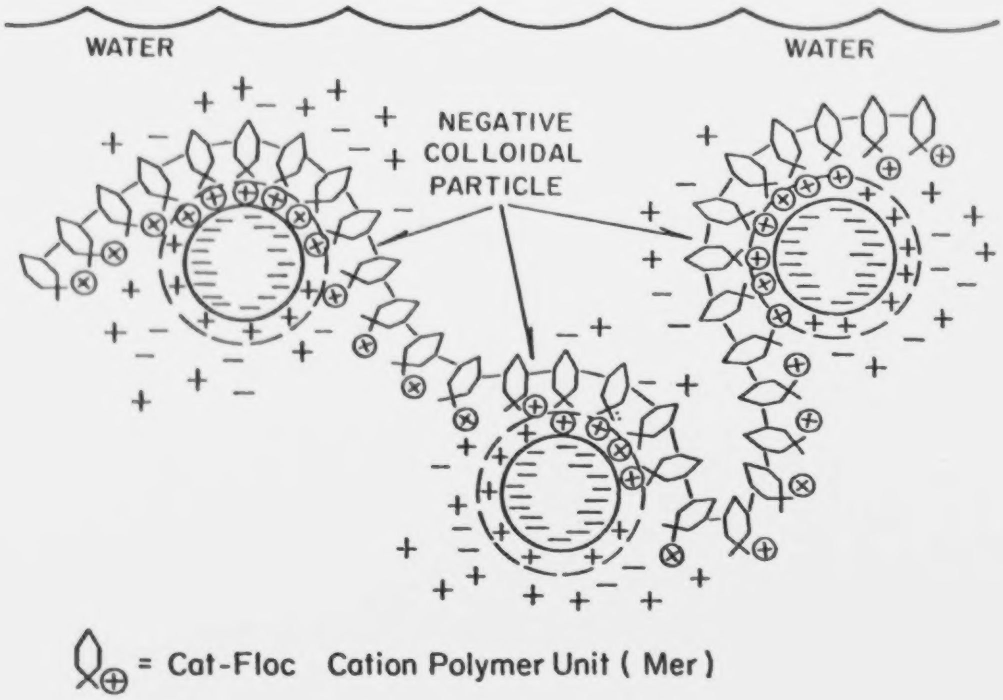

WATER
WATER
NEGATIVE COLLOIDAL PARTICLE
= Cat-Floc Cation Polymer Unit (Mer)

Fig. 6.34 Drawing illustrating the coagulation-flocculation reaction produced by Cat-Floc

This comes about either as a result of the alkalinity of the water or as a result of increasing the pH by the use of lime or soda ash. The metal ions will combine with the hydroxide to form gelatinous products which will enmesh suspended particles within them.

$$(\text{Metal Ion})^+ + OH^- \rightleftharpoons \text{Gelatinous Complex}$$

6.412 Properties of Some Common Coagulants

Several coagulants are now available on the market. With the advent of polymers, many of the inorganics are being replaced with organics (polymers). However, for economic considerations, many of the tried and tested inorganics are still used widely and should be considered. Among them, the most common are compounds of aluminum, iron and lime.

Aluminum compounds are generally categorized as alum and may be purchased in both liquid and dry forms. Dry alum $Al_2(SO_4)_3 \cdot 14\ H_2O$) is partially hydrated, therefore slightly *HYGROSCOPIC*[17] and should be stored in an area of controlled humidity. Dry alum is not corrosive unless it absorbs moisture. Dry alum is sold as approximately 17 percent as Al_2O_3. When added to water, it is acidic and a 1 percent solution will have a pH of 3.5. In general, the reaction of alum, although complex, depending upon the type of sludge, can be simplified by considering its reaction with hydroxyl ion. Aluminum ion goes into solution by the following dissociation.

$$Al_2(SO_4)_3 \rightleftharpoons 2Al^{+3} + 3(SO_4)^{-2}$$

With hydroxyl ions from the water,

$$H_2O \rightleftharpoons H^+ + OH^-$$

the following occurs:

$$2\ Al^{+3} + 6\ OH^- \rightleftharpoons 2\ Al(OH)_3.$$

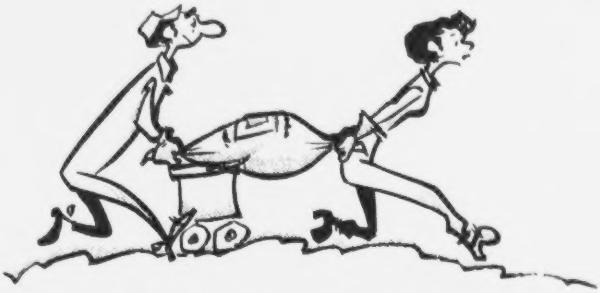
The hydrated precipitate is the mechanism by which coagulation is enhanced. Aluminum ion may also combine with other negative ions in a similar manner to give the similar net result.

Iron compounds are also effective coagulants, especially in the formation of hydrated complexes. The most commonly used are ferric chloride ($FeCl_3$), ferrous chloride ($FeCl_2$) and ferrous sulfate ($FeSO_4$). All such compounds are corrosive, difficult to dissolve in water and may, if added in excess, create an excess of iron in the effluent.

Ferric chloride is often shipped as a dark brown, oily liquid and is very corrosive to many common materials. Ferric chloride will characteristically stain anything with which it comes into contact and, therefore, precautions should be taken. Ferrous chloride is slightly less corrosive. Ferric sulfate (also called copperas) is available in a dry powder, granule, crystal or lump and must be handled with care. If dry at temperatures less than 68°F (20°C), it is efflorescent (will form a powder or cust on the surface), however, if moisture is present, it will hydrate rapidly. If it comes into contact with quicklime, a high degree of heat is created and an explosive hazard results.

Lime is sold in the forms of quicklime (CaO) and hydrated lime ($Ca(OH)_2$). The density is approximately 55 to 75 pounds per cubic foot and it is highly alkaline. The reaction is somewhat different from the other coagulating chemicals in that it is indirect. Addition of lime to water creates a condition in which calcium carbonate ($CaCO_3$) is precipitated. As the pH is elevated above 10.5, magnesium hydroxide ($Mg(OH)_2$) is formed from the natural magnesium present. This hydroxide possesses the coagulating properties.

Other inorganics commonly in use are soda ash (Na_2CO_3), caustic soda (NaOH) and carbon dioxide (CO_2). Each is used in conjunction with other organic coagulants as control mechanisms for pH. This is especially true when using lime since the high pH maintenance is so important. Both soda ash and caustic soda are alkaline while carbon dioxide is acidic in solution with the formation of carbonic acid.



Numerous organic polymers are available which possess equivalent or superior coagulating properties to the inorganics without many of the handling problems. These generally function by means of interparticle bridging or by charge neutralization. Sometimes a polymer is used in conjunction with an inorganic coagulant to enhance the coagulating process even more. In this case, the polymer is considered to be a coagulant aid.

Polymers are purchased in both powdered and liquid forms. However, the liquid is more convenient in that it may be used directly, thus eliminating the need to make up working solutions. Because many polymers tend to cake upon small additions of water, direct use of powders may cause line plugging at the point of discharge into a wastewater stream. Caution must be observed in either case to prevent spillage. Polymers possess a lubricating property which presents a safety hazard if left unattended on walkways. A chlorine solution can be used to clean up a spilled polymer.

6.413 Testing Coagulants for Dosage Selection

The most accepted testing procedure for both coagulant dose and the determination of optimum coagulating conditions is the jar test. The jar test is especially versatile in that it is able to simulate, on a batch basis, the conditions expected to take place in the coagulating operation. In essence, it is a bench-scale model of the actual plant process in which a sample of the water to be treated is given the same sequence of operations that it would have on a full scale. A special jar test apparatus (Fig. 6.35) is used consisting of a lighted platform over which are suspended several paddles (usually six) on a single drive mechanism. The speed of the paddles can be altered so as to simulate both the rapid mix and the flocculation operations. Clarification is simulated by turning the paddles off.

The jar test uses up to six separate samples of the raw wastewater set on the apparatus. The motor is turned on and the paddles are set rotating at a speed corresponding to that of the rapid mix of the plant being modeled. Rapid mix continues for a duration which approximates the normal residence time of a plug of water passing through the rapid mix tanks. The proposed concentrations of the coagulant to be used are added to separate vessels at a point similar to the actual rapid mix, usually at the start of the test.

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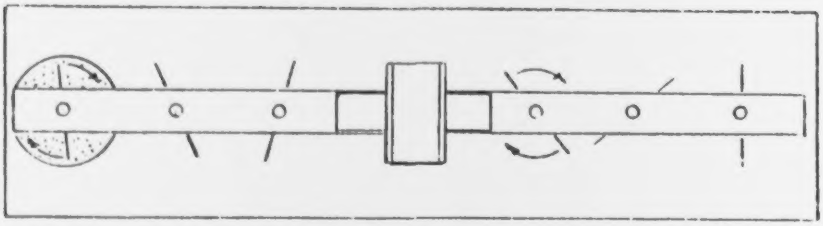
[17] *Hygroscopic (HI-grow-SKOP-ic). A substance that absorbs or attracts moisture from the air.*



Jar Test Apparatus

Top View

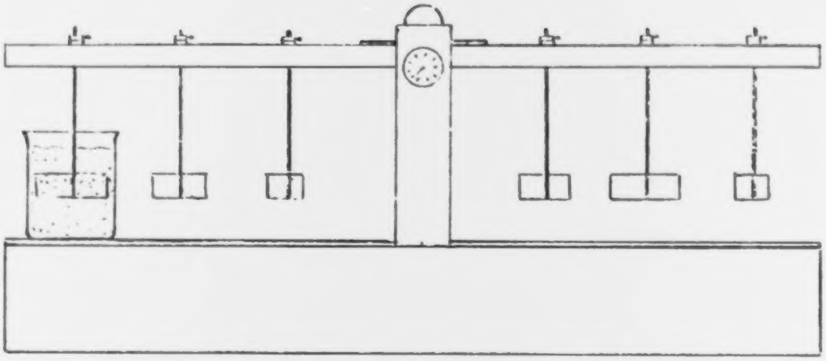


Fig. 6.35 Jar test experiment

Upon completion of the rapid mix simulation, the paddles are slowed to imitate the speed of the flocculation paddles. Once again, duration is that which is estimated as the time necessary for a plug of water to pass through the flocculators. Upon completion of this stage, the paddles are shut off, and the mixture is allowed to settle quiescently for approximately 10 to 30 minutes or for whatever time is necessary for the bulk of the particles to precipitate. Visual inspection is made of the settling characteristics of each dose. Supernatant may be decanted and tested for turbidity, color or some other measure of effective removal of suspended matter. From such observations, the optimum coagulant dose can be selected.

6 FOR SURE
3 YES
1 OK
5 RIGHT
4 TOO TRUE
2 UH-HUH

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 451.

6.4A List the operations involved in chemical coagulation.

6.4B What is coagulation?

6.4C What is flocculation?

6.4D What can happen if the rapid mix is too long?

6.4E Why are polymers considered more convenient in the liquid form?

6.42 Description of Equipment

6.420 Storage and Delivery of Coagulant

Coagulants can be divided physically into two categories, liquid and solid. The physical category will necessarily dictate the type of equipment necessary to accommodate it.

Solids may be dissolved before actual use and thereby may use some equipment similar to that for liquid coagulants. Storage of all inorganic solids should be in dry tanks or bins because almost all inorganic solids exhibit caustic or corrosive properties if they become moist. Bins for powdered solids generally will be provided with a dust collector to keep the material ventilated as well as contained as a precaution against flash combustion. Exit to the feed system is often assisted by a shaker or vibrator to prevent caking of the material. In the case of some limes, a slaker is often found at this point.

Solid feed systems are of three types — volumetric, belt gravimetric or loss-in-weight gravimetric. Volumetric feeders are generally screw type (Fig. 6.36). These may be variable pitch, in which the screw is tapered from the point of accepting material to the point of discharge, or they may be a constant pitch, reciprocating feed systems. The latter has two screws rotating in opposite directions and has two discharge points while the former has one discharge.

Belt gravimetric feeders consist of a feed belt and a weight control system. The rate of feed may be changed either by varying the ratio of weight accepted per foot of belt or by increasing the belt speed. In the case of volumetric, the quantity of feed is fixed by the size of the screw and the feed rate may be varied by adjusting the speed of the screw.

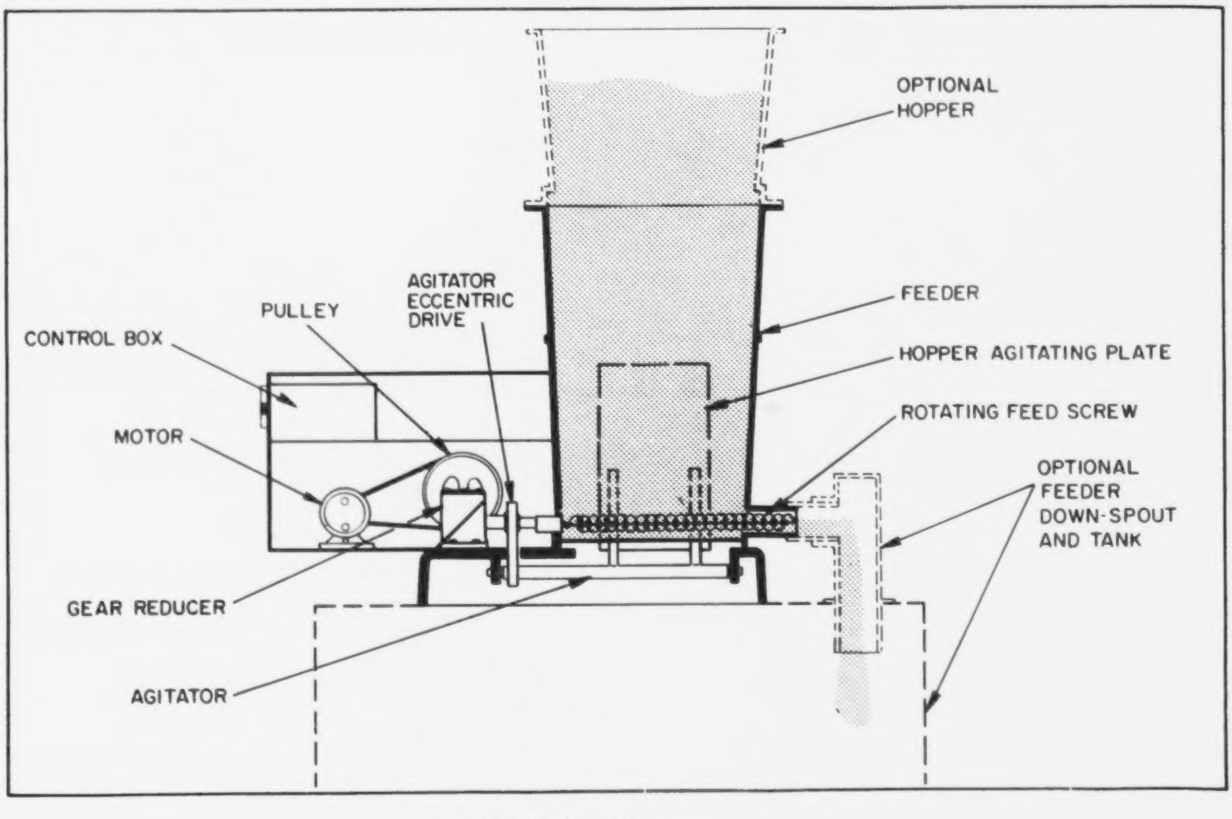


Fig. 6.36 Volumetric screw feeder

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

The most accurate solid feed system is the loss-in-weight (gravimetric) in which both the material hopper and feeding mechanisms are located on enclosed scales. The feed rate controller reacts to the scale poise weight, thereby delivering the chemical at the desired rate.

Liquid coagulants may be delivered by any one of a number of systems including plunger pumps, positive displacement diaphragm pumps (Fig. 6.37), centrifugal pumps and rotodip pumps. Positive displacement pumps (rotary) (Fig. 6.38) must have a recirculation line back to the storage tank to prevent excess flow causing rupture due to back pressure.

As previously noted, many solids are converted to liquid form before entry into the system. This is especially true with lime (Fig. 6.39), caustic (Fig. 6.40), alum and organic polymers. (Figs. 6.41 and 6.42). In such cases, measured amounts of the dry chemical are passed to a make-up or slurry tank in which a desired fluid dilution is made. Dry chemicals may also be added directly under the assistance of water jets spraying at the points of entry. The latter method is an acceptable means of delivering dry polymer.

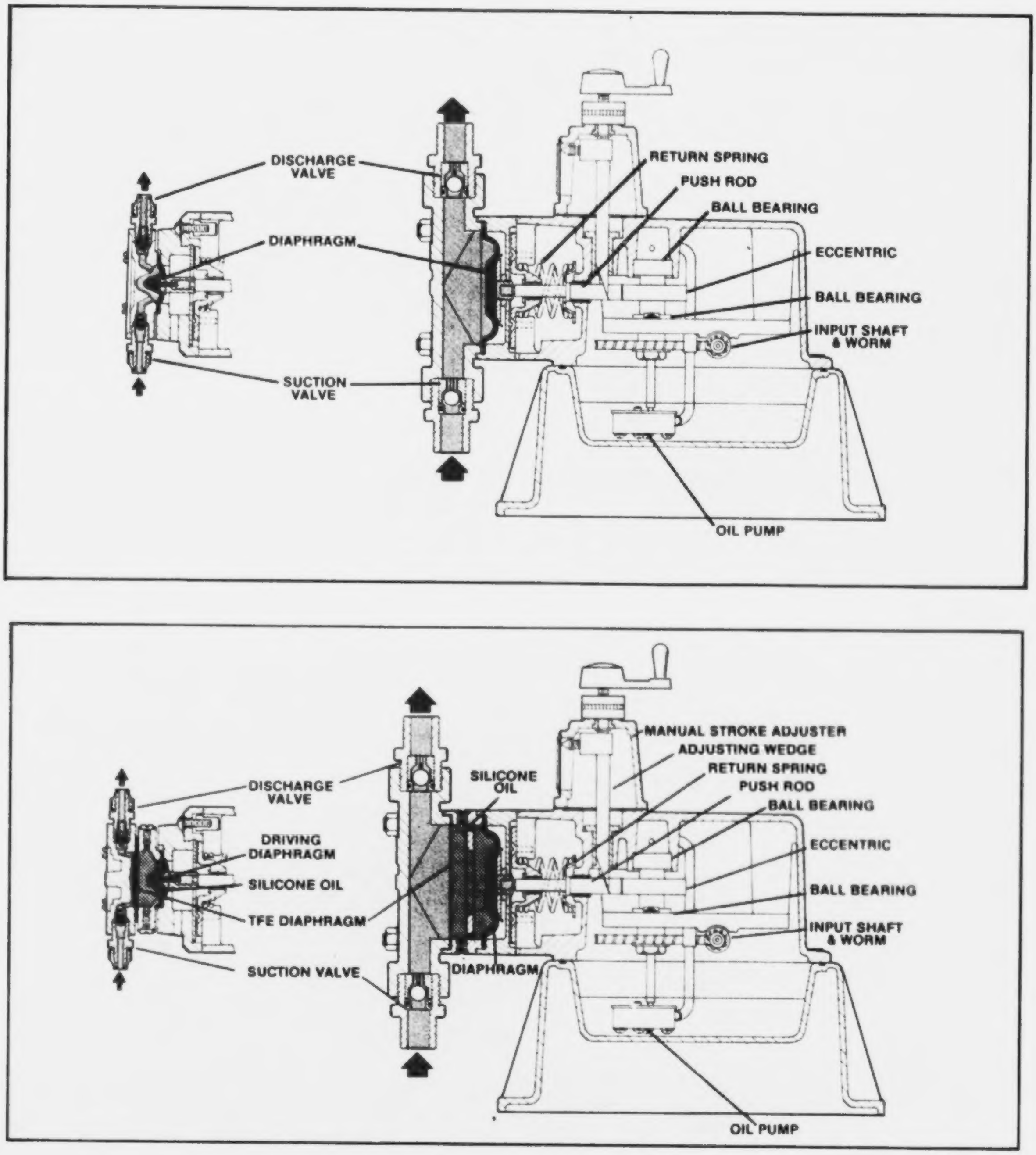

DISCHARGE VALVE
DIAPHRAGM
SUCTION VALVE
RETURN SPRING
PUSH ROD
BALL BEARING
ECCENTRIC
BALL BEARING
INPUT SHAFT & WORM
OIL PUMP
DISCHARGE VALVE
DRIVING DIAPHRAGM
SILICONE OIL
TFE DIAPHRAGM
SUCTION VALVE
SILICONE OIL
DIAPHRAGM
MANUAL STROKE ADJUSTER
ADJUSTING WEDGE
RETURN SPRING
PUSH ROD
BALL BEARING
ECCENTRIC
BALL BEARING
INPUT SHAFT & WORM
OIL PUMP

Fig. 6.37 Positive displacement diaphragm pumps

(Permission of Wallace & Tiernan Division, Pennwalt Corporation)

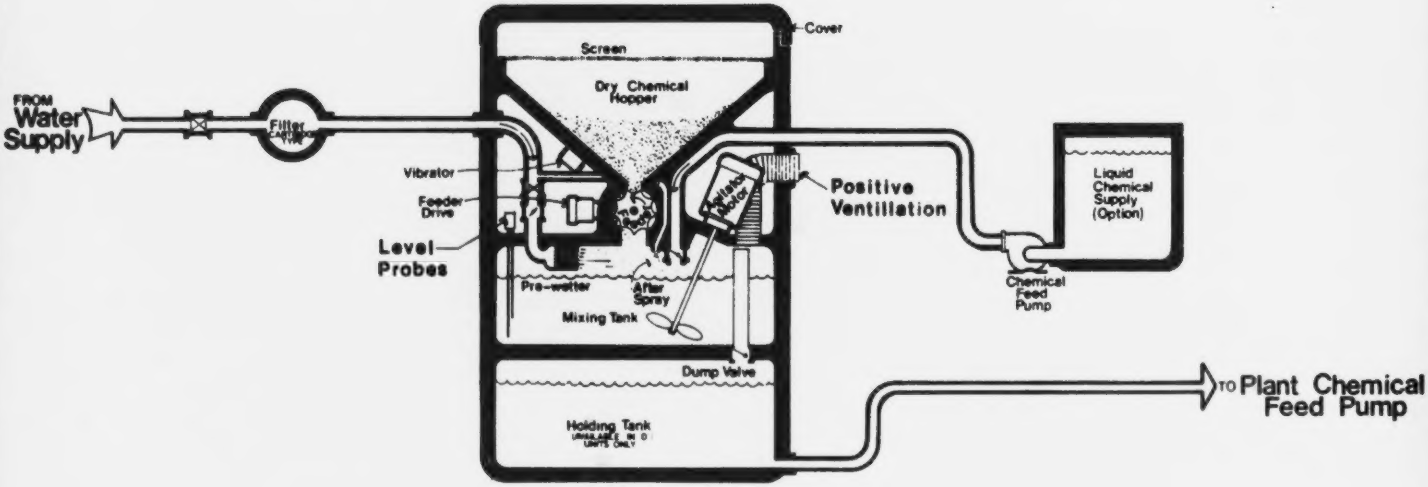

FROM Water Supply
Filter CARTRIDGE TYPE
Cover
Screen
Dry Chemical Hopper
Vibrator
Feeder Drive
Level Probes
Agitator Motor
Positive Ventilation
Liquid Chemical Supply (Option)
Chemical Feed Pump
Pre-wetter
After Spray
Mixing Tank
Dump Valve
Holding Tank
(AVAILABLE IN D UNITS ONLY)
TO Plant Chemical Feed Pump

Fig. 6.38 Positive displacement rotary solid feeder

(Permission of Neptune Microfloc)

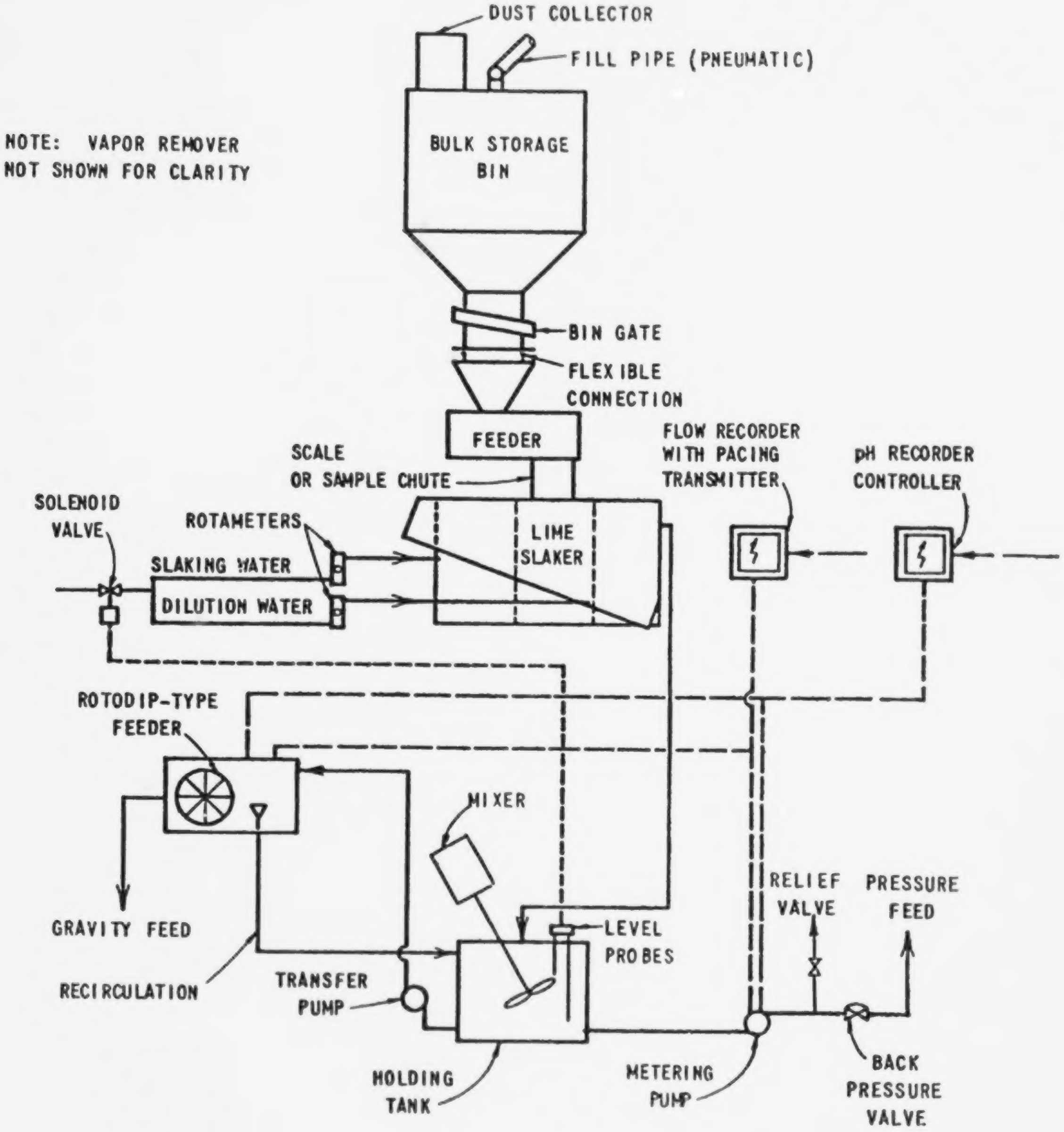

DUST COLLECTOR
FILL PIPE (PNEUMATIC)
NOTE: VAPOR REMOVER NOT SHOWN FOR CLARITY
BULK STORAGE BIN
BIN GATE
FLEXIBLE CONNECTION
FEEDER
SCALE OR SAMPLE CHUTE
FLOW RECORDER WITH PACING TRANSMITTER
pH RECORDER CONTROLLER
SOLENOID VALVE
ROTAMETERS
SLAKING WATER
DILUTION WATER
LIME SLAKER
ROTODIP-TYPE FEEDER
MIXER
GRAVITY FEED
RECIRCULATION
TRANSFER PUMP
LEVEL PROBES
RELIEF VALVE
PRESSURE FEED
HOLDING TANK
METERING PUMP
BACK PRESSURE VALVE

Fig. 6.39 *Typical lime feed system*

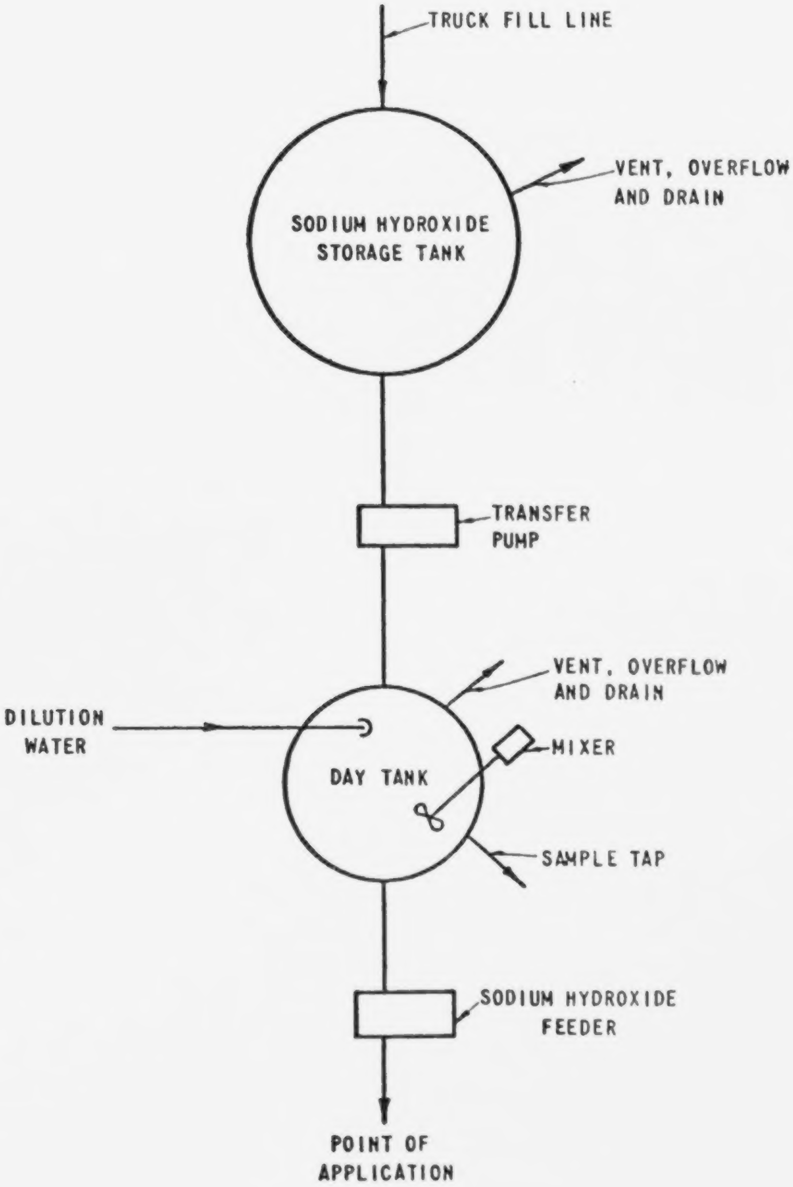

TRUCK FILL LINE
VENT, OVERFLOW AND DRAIN
SODIUM HYDROXIDE STORAGE TANK
TRANSFER PUMP
VENT, OVERFLOW AND DRAIN
DILUTION WATER
MIXER
DAY TANK
SAMPLE TAP
SODIUM HYDROXIDE FEEDER
POINT OF APPLICATION

Fig. 6.40 Typical caustic soda feed system

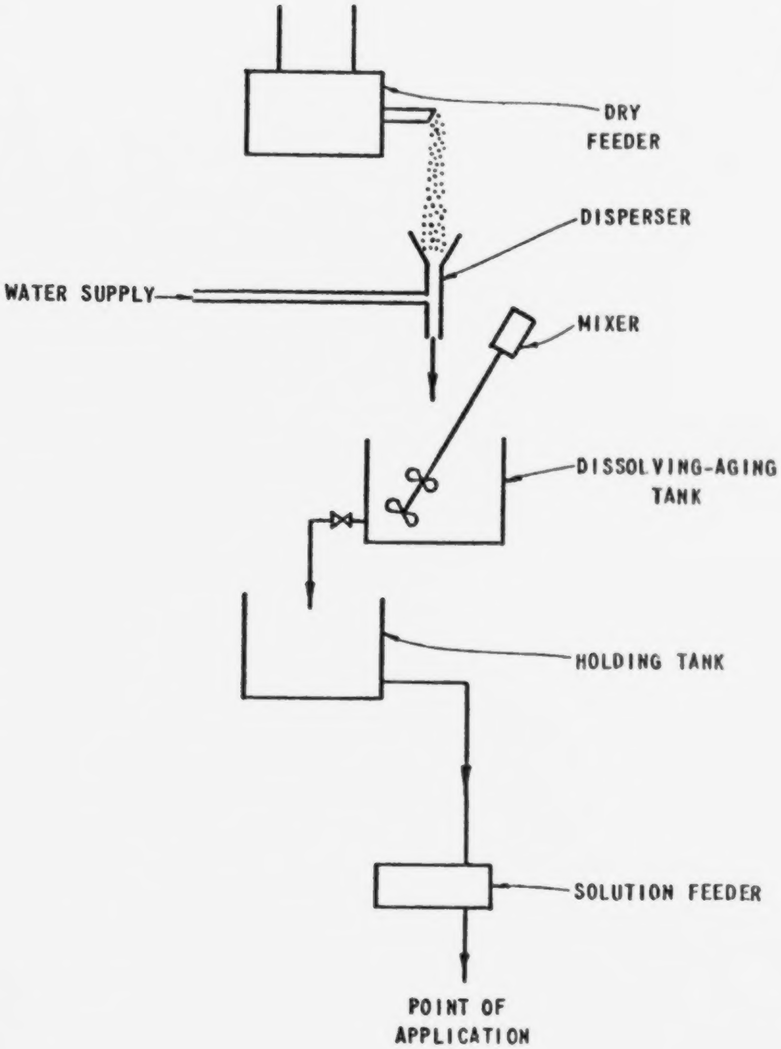

DRY
FEEDER
DISPERSER
WATER SUPPLY
MIXER
DISSOLVING-AGING
TANK
HOLDING TANK
SOLUTION FEEDER
POINT OF
APPLICATION

Fig. 6.41 Typical schematic of a dry polymer feed system

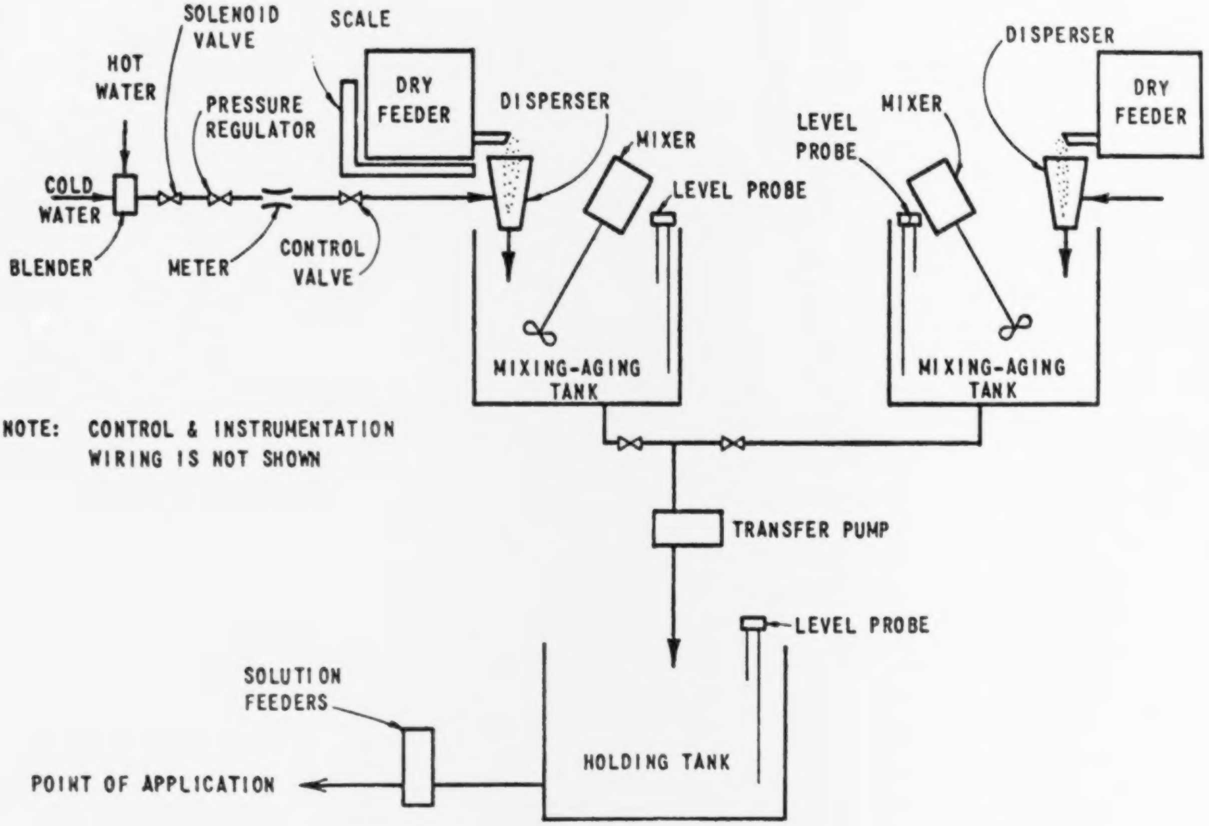

SOLENOID VALVE
SCALE
HOT WATER
DRY FEEDER
DISPERSER
PRESSURE REGULATOR
MIXER
COLD WATER
LEVEL PROBE
BLENDER
METER
CONTROL VALVE
MIXING-AGING TANK
DISPERSER
DRY FEEDER
MIXER
LEVEL PROBE
MIXING-AGING TANK
NOTE: CONTROL & INSTRUMENTATION WIRING IS NOT SHOWN
TRANSFER PUMP
LEVEL PROBE
SOLUTION FEEDERS
HOLDING TANK
POINT OF APPLICATION

Fig. 6.42 Typical automatic dry polymer feed system

6.421 Mixing Units

Rapid mixing may be accomplished in one of three modes: (1) high-speed mixers (impeller or turbine), (2) in-line blenders and pumps, and (3) baffled compartments or pipes (static mixers). The use of high-speed mechanical mixers is most common. They are often seen in parallel to increase residence time. Static mixers make use of fluid passing through baffled chambers at high velocities to bring about turbulence and mixing. In-line blenders and pumps accomplish the same by virtue of a high velocity.

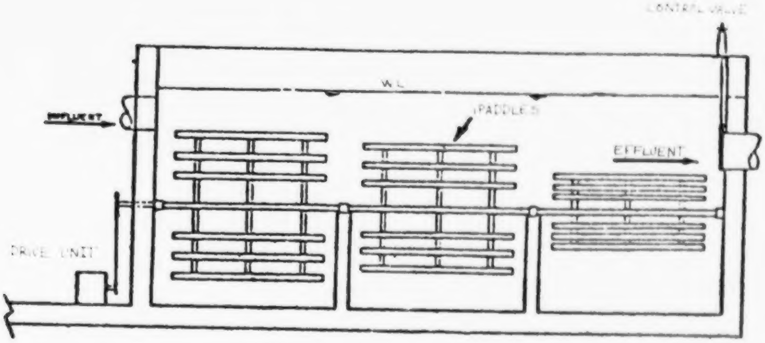
6.422 Flocculators

Mechanical flocculating units (Fig. 6.43) may be rotary, horizontal shaft-reel type, rotary-shift turbine or rotary reciprocating. All three rotary systems possess vertical shafts. Standard rotary and rotary reciprocating units use paddle impellers, the latter consisting of more than one shaft rotating in opposite directions.

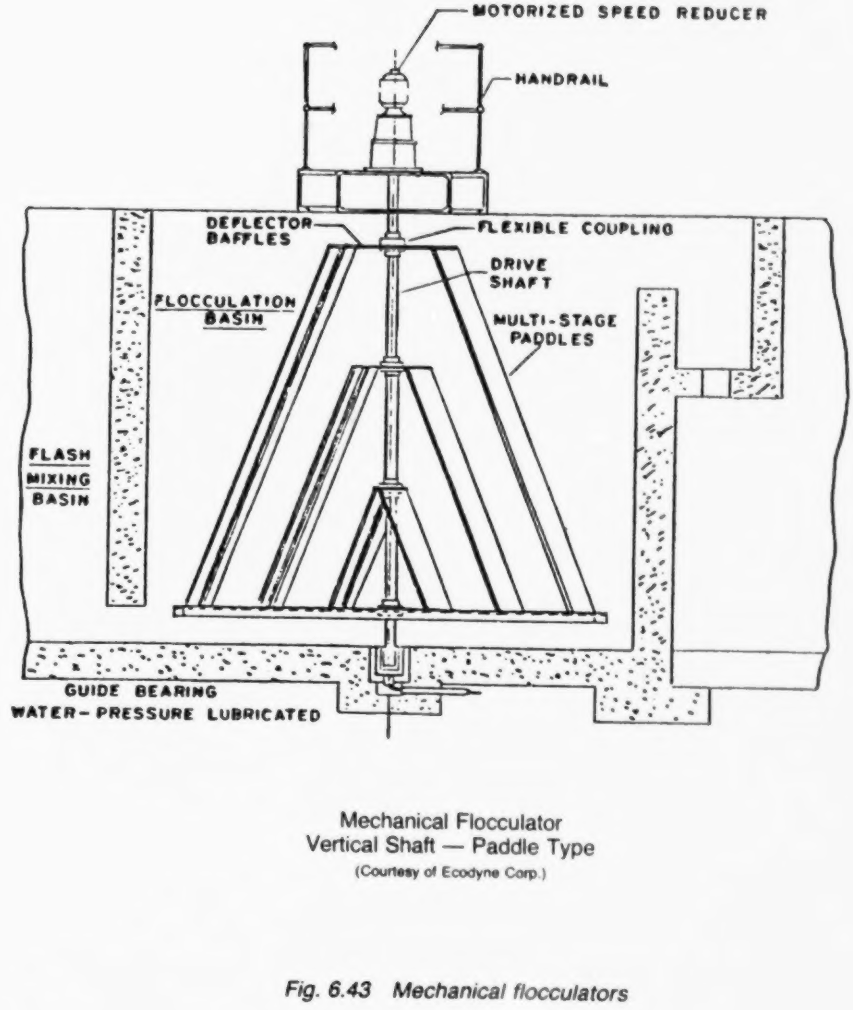
In all flow-through flocculators, tapered flocculation is found to be most beneficial. By this method, a small dense floc is formed initially followed by aggregation to form a more dense, dispersed floc. This is accomplished on single shafts by variation of the paddle sizes. On multiple-shaft units, variation of the speed of the individual units and/or the number of paddles per shaft is effective.

6.423 Clarifiers (Also see Chapter 5, "Sedimentation and Flotation," Volume I, *OPERATION OF WASTEWATER TREATMENT PLANTS*

Clarifiers can take on two basic configurations (Fig. 6.44) based upon the flow character, that is, vertical or horizontal flow. Horizontal flow is the most common, taking on both rectangular and circular configurations.

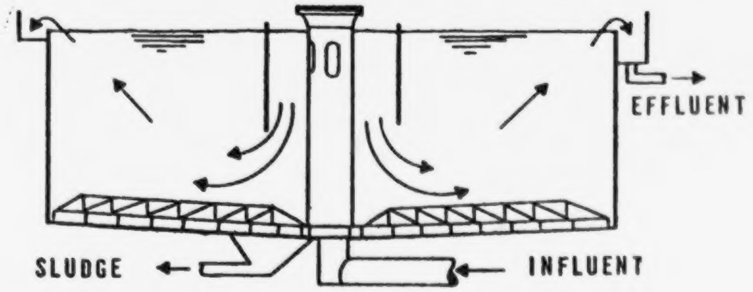

CONTROL VALVE
W.L.
INFLUENT
(PADDLES)
EFFLUENT
DRIVE UNIT

Mechanical Flocculation Basin
Horizontal Shaft-Reel Type

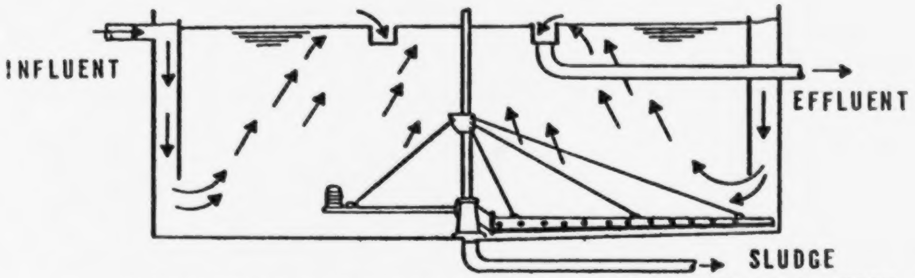

MOTORIZED SPEED REDUCER
HANDRAIL
DEFLECTOR BAFFLES
FLEXIBLE COUPLING
DRIVE SHAFT
FLOCCULATION BASIN
MULTI-STAGE PADDLES
FLASH MIXING BASIN
GUIDE BEARING
WATER-PRESSURE LUBRICATED

Mechanical Flocculator
Vertical Shaft — Paddle Type
(Courtesy of Ecodyne Corp.)

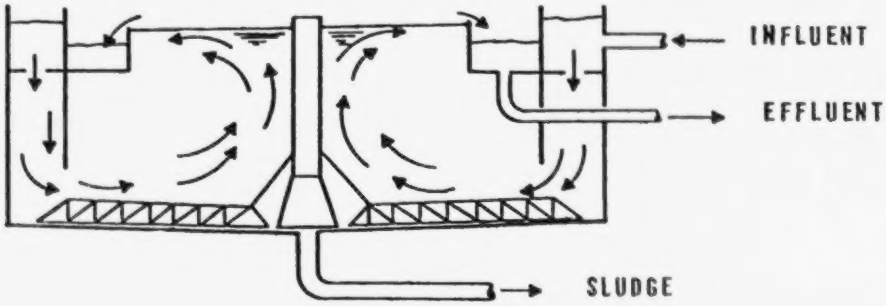
Fig. 6.43 Mechanical flocculators



(a) CIRCULAR CENTER-FEED CLARIFIER WITH A SCRAPER SLUDGE REMOVAL SYSTEM



(b) CIRCULAR RIM-FEED, CENTER TAKE-OFF CLARIFIER WITH A HYDRAULIC SUCTION SLUDGE REMOVAL SYSTEM



(c) CIRCULAR RIM-FEED, RIM TAKE-OFF CLARIFIER

Fig. 6.44 Typical clarifier configurations

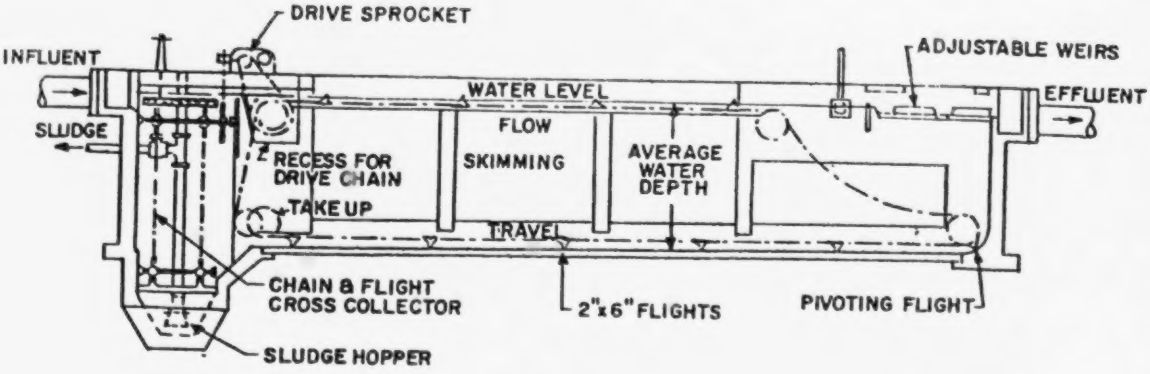
Rectangular clarifiers (Fig. 6.45) with horizontal flow have the influent entering at one end. Flow generally hits a baffle and moves by gravity to the opposite end where the effluent overflows the outlet weirs. A surface skimmer made up of flights pushes oil and floating debris to a spiral collector located at one end. Settled sludge is moved by flights along the bottom to a sludge hopper where it is collected and pumped to a dewatering facility.

Circular clarifiers with horizontal flow take on one of three configurations.

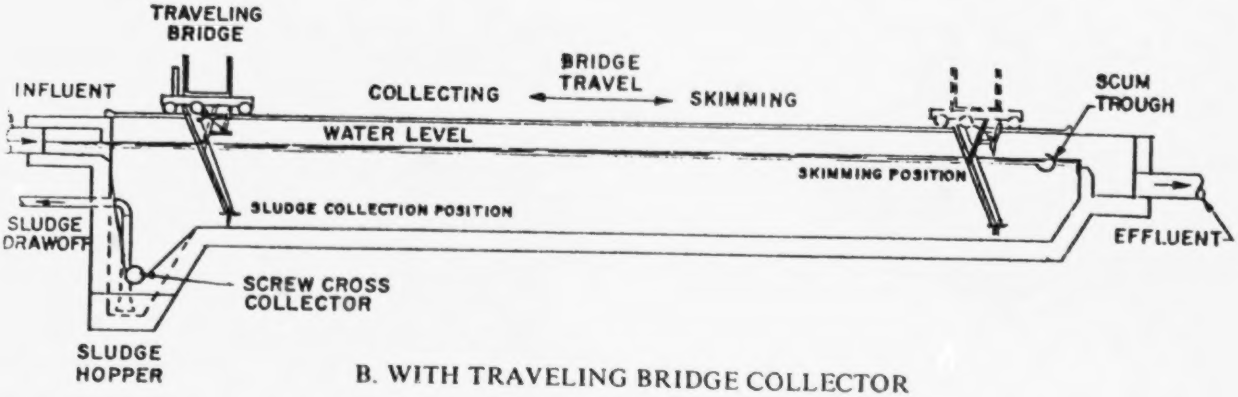
1. Center influent with radial effluent,
2. Radial influent with center effluent, and
3. Radial influent and effluent.

In each case, sludge is collected at the center of the conical base. Oil and scum are skimmed by a radial arm at the surface of the water which deposits the material into a sump.

Vertical flow units (Fig. 6.46) have the general distinction of the influent flowing along the bottom and rising toward the top to be discharged over the effluent weir. One advantage of vertical flow clarifiers is that flow can be forced up through the sludge blanket, thus aiding in solids retention and improving flow control. Both rectangular and circular configurations exist.


DRIVE SPROCKET
INFLUENT
ADJUSTABLE WEIRS
WATER LEVEL
EFFLUENT
SLUDGE
FLOW
RECESS FOR DRIVE CHAIN
SKIMMING
AVERAGE WATER DEPTH
TAKE UP
TRAVEL
CHAIN & FLIGHT CROSS COLLECTOR
2"x6" FLIGHTS
PIVOTING FLIGHT
SLUDGE HOPPER

A. WITH CHAIN AND FLIGHT COLLECTOR


TRAVELING BRIDGE
INFLUENT
COLLECTING
BRIDGE TRAVEL
SKIMMING
SCUM TROUGH
WATER LEVEL
SKIMMING POSITION
SLUDGE DRAWOFF
SLUDGE COLLECTION POSITION
EFFLUENT
SCREW CROSS COLLECTOR
SLUDGE HOPPER

B. WITH TRAVELING BRIDGE COLLECTOR

Fig. 6.45 Rectangular sedimentation tanks

(Courtesy of FMC Corp.)

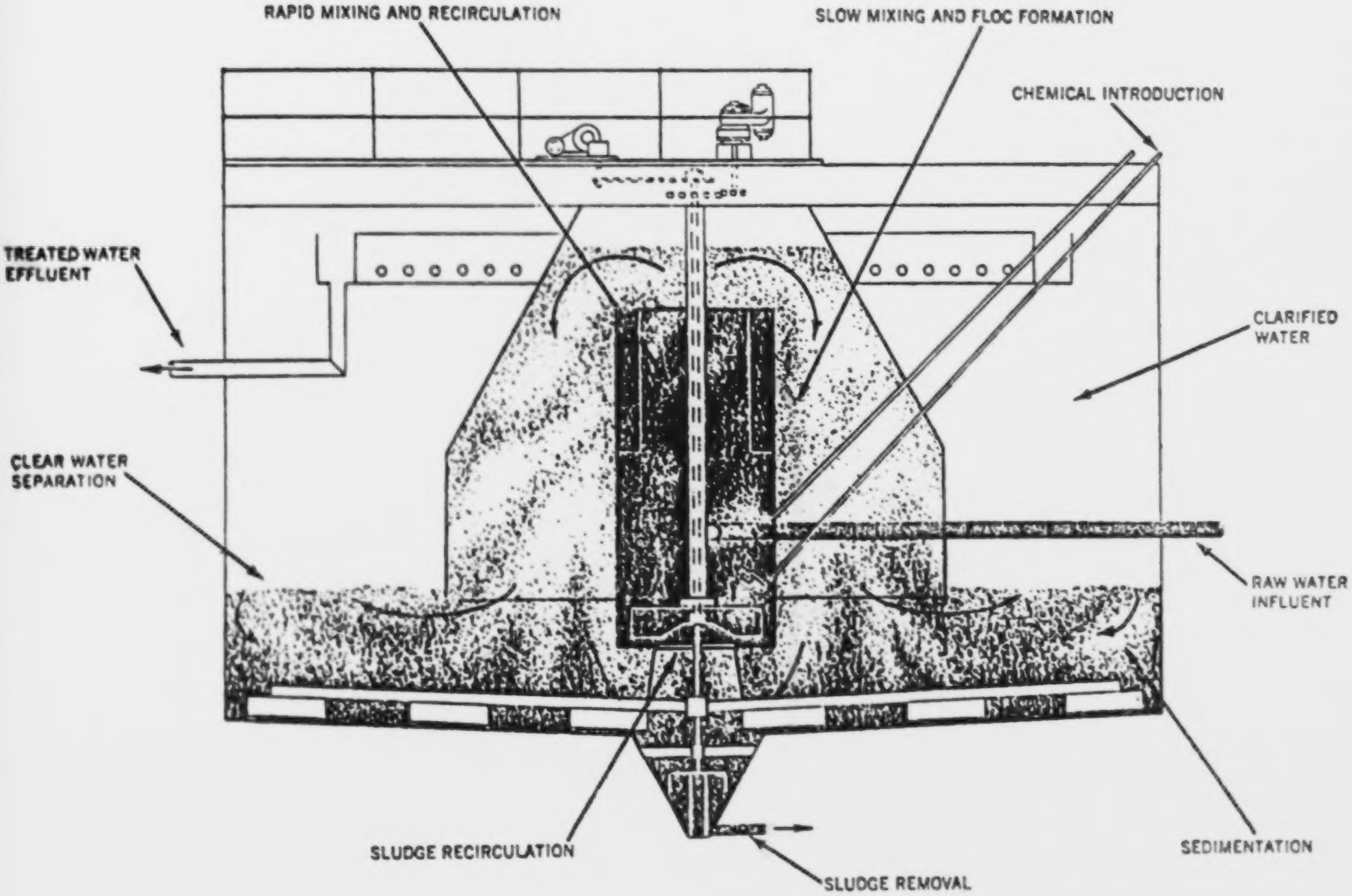

RAPID MIXING AND RECIRCULATION
SLOW MIXING AND FLOC FORMATION
CHEMICAL INTRODUCTION
TREATED WATER EFFLUENT
CLARIFIED WATER
CLEAR WATER SEPARATION
RAW WATER INFLUENT
SLUDGE RECIRCULATION
SEDIMENTATION
SLUDGE REMOVAL

Fig. 6.46 Solids contact clarifier without sludge blanket infiltration

(Courtesy of Econodyne Corp.)

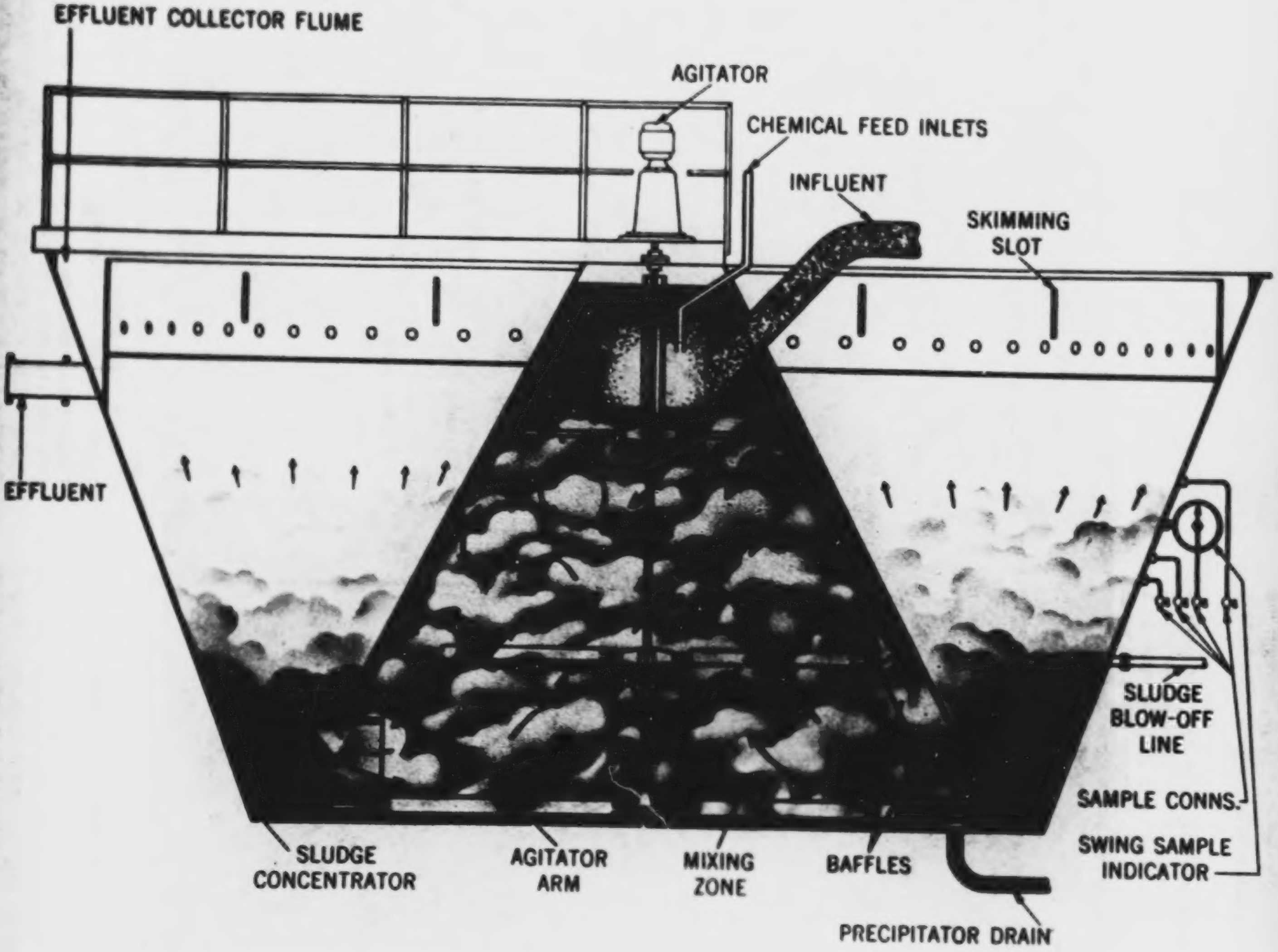

EFFLUENT COLLECTOR FLUME
AGITATOR
CHEMICAL FEED INLETS
INFLUENT
SKIMMING SLOT
EFFLUENT
SLUDGE BLOW-OFF LINE
SAMPLE CONNS.
SWING SAMPLE INDICATOR
SLUDGE CONCENTRATOR
AGITATOR ARM
MIXING ZONE
BAFFLES
PRECIPITATOR DRAIN

Fig. 6.47 Solids contact clarifier with sludge blanket filtration

(Courtesy of the Permutit Co.)

Circular configurations have solids contact units in which all three activities leading up to and including coagulation and precipitation take place (Fig. 6.47). Influent becomes rapidly mixed with the coagulant at the influent discharge and flows down through a center baffle. Flocculation occurs in this zone. Flow proceeds radially upward through the sludge blanket and clarification occurs. Effluent discharge is radial.

Rectangular configurations may have tube and lamella separators in which settling becomes compartmentalized. Tube settlers (Figs. 6.48, 6.49, and 6.50) consist of a collection of closely packed small-diameter tubes placed at an angle. Flow proceeds upward as sludge settles downard. The use of parallel plates rather than tubes is the distinction of a lamella separator. Flow in this case is concurrent. Both configurations depend upon the assumption that the paths of all discrete particles with the same settling velocities will be straight parallel lines. In the above two configurations, the surface area of the clarifier is effectively increased without increasing the actual size.

6.43 The Precipitation Process

6.430 Factors in Design Consideration

The operator should consider at least four factors in the design of a clarifier. These are detention time, weir overflow rate, surface loading rate, and solids loading. Each of these factors is readily calculated and will give the operator an indication of clarifier efficiency.

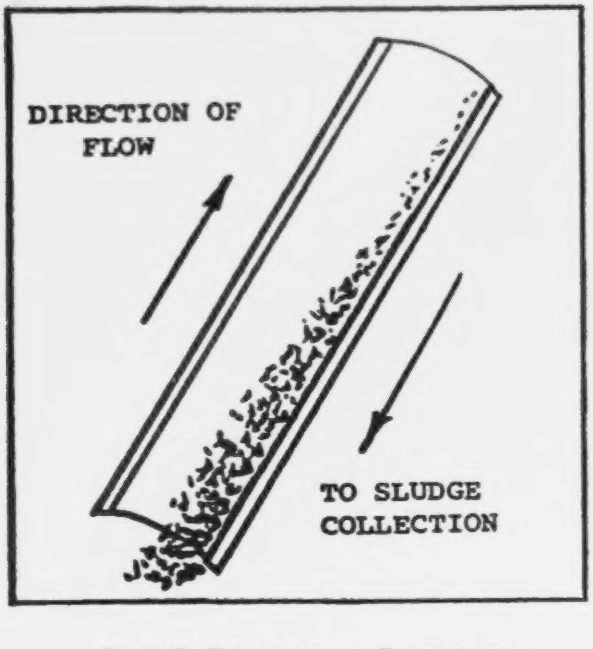


Fig. 6.48 Tube settlers — flow pattern

Detention time is the length of time it would take a plug of water to enter a clarifier and to exit in the effluent. This is related to clarifier efficiency in that particles should be allowed ample time to settle out. If the detention time is less than the settling rate, then there will be a carryover of particles into the effluent. Detention time is calculated knowing the flow and tank dimensions as follows:

$$\text{Tank Volume, cu ft} = \text{Length, ft} \times \text{Width, ft} \times \text{Depth, ft}$$

or

$$\text{Tank Volume, cu m} = \text{Length, m} \times \text{Width, m} \times \text{Depth, m}$$

and

$$\text{Detention Time, hr} = \frac{\text{Tank Vol, cu ft} \times \frac{7.48\text{ gal}}{\text{cu ft}} \times \frac{24\text{ hr}}{\text{day}}}{\text{Flow, gal/day}}$$

or

$$\text{Detention Time, hr} = \frac{\text{Tank Vol, cu m} \times 24\text{ hr/day}}{\text{Flow, cu m/day}}$$

If the detention time proves to be less than the settling rate (as shown by results of laboratory tests), then it may be necessary to increase the clarifier capacity by placing other basins into operation.

The weir overflow rate expresses the quantity of water which passes out of the clarifier in relation to the lineal feet of weir available. Weir overflow rate is expressed as follows:

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow, gal/day}}{\text{Length of Weir, lineal feet}}$$

or

$$\text{Weir Overflow Rate, cu m/day/m} = \frac{\text{Flow, cu m/day}}{\text{Length of Weir, m}}$$

Surface loading rate expresses the quantity of water being treated in relation to the available clarifier surface. As previously stated, sedimentation efficiency increases with increased surface area. Surface loading rate may be expressed as follows:

$$\text{Surface Loading Rate, gpd/sq ft} = \frac{\text{Flow, gal/day}}{\text{Clarifier Surface Area, sq ft}}$$

or

$$\text{Surface Loading Rate, cu m/day/sq m} = \frac{\text{Flow, cu m/day}}{\text{Clarifier Surface Area, sq m}}$$

Another very important loading guideline for clarifiers is the solids loading. Solids loadings are especially important for industrial waste treatment because the solids carried by industrial wastewater may be significantly different from solids in municipal wastewaters.

$$\text{Solids Loading, lbs/hr/sq ft} = \frac{\text{Solids, lbs/hr}}{\text{Clarifier Surface Area, sq ft}}$$

or

$$\text{Solids Loading, kg/hr/sq m} = \frac{\text{Solids, kg/hr}}{\text{Clarifier Surface Area, sq m}}$$

The above characteristics are useful when compared with the original design considerations and specifications in attempting to diagnose the possible causes for clarifier inefficiency. These, coupled with the results of laboratory tests, such as dye tracer studies, will aid the operator in troubleshooting clarifier performance problems.

Other physical characteristics will also affect clarifier efficiency. One important feature is the settling characteristics of the particles. Settling rate may be affected by many factors including particle size, shape, temperature of the surrounding water and particle weight in relationship to that of the surrounding water. Particles of greater weight and density will settle faster than those of lesser density. The horizontal velocity and the tank depth will also come into play in determining how long it takes a particle to settle.

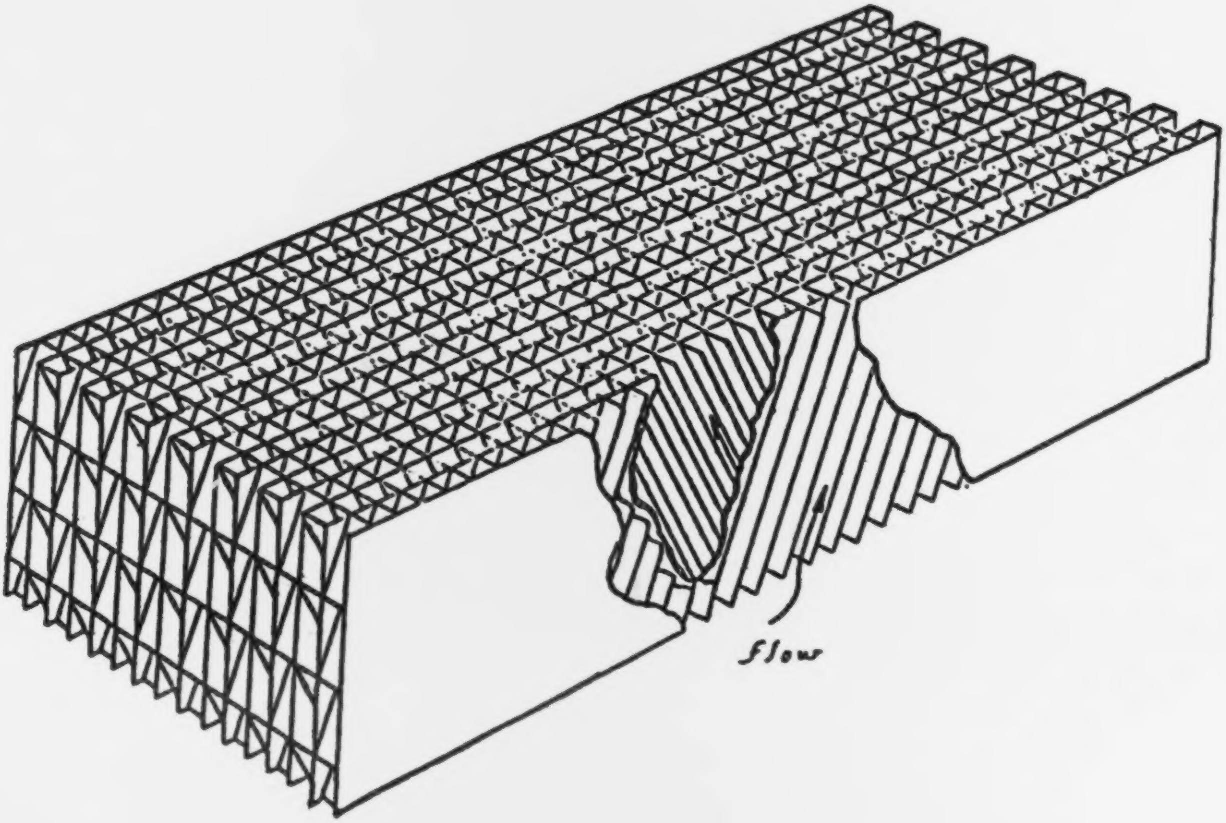


Fig. 6.49 Module of steeply inclined tubes

(Courtesy Neptune Microfloc, Inc.)

A particle settling quiescently (in still water) will tend to settle in a path perpendicular to the settling surface. With flow through a clarifier, force is applied to a particle causing it to settle in a plane diagonal to the settling surface. Since it now has a longer path to travel, the particle will take slightly longer to settle.

The ultimate settling velocity of the particle will be affected by the flow, the viscosity of the water and the settling characteristics of the particle. Temperature may play a vital role in the settling characteristics of the particle. With decreasing temperature, water becomes more dense and more viscous. Consequently, the space between the water molecules becomes more restricting on the particle's ability to settle. Increased temperature has the opposite effect. Settling rate is therefore greater at a warmer temperature than it is at a lower temperature.

SHORT-CIRCUITING[18] of flow can adversely affect clarifier efficiency. This occurs when the flow is not homogenous (completely uniform) throughout the tank. That is to say, there exist zones or layers where the flow is either faster or slower than the surrounding areas. If velocity is too high in an area, suspended material may pass out of the clarifier without settling. Too slow a velocity will cause dead spaces with the danger of an induced septic condition (assuming the presence of organic or other biologically degradable material).

Short-circuiting may be caused by differences in water density due to different temperatures existing at the surface and the bottom of the clarifier. This is especially true in temperate climates during the winter and summer seasons. Density differences may also be induced by a high suspended solids content in the influent. Short-circuiting may be made worse by high inlet velocities, high outlet weir rates, and strong winds blowing along the tank surface. In all cases, the most effective solution is the use of weir plates, baffles and port openings to produce a flow velocity throughout the clarifier that is as even as possible.

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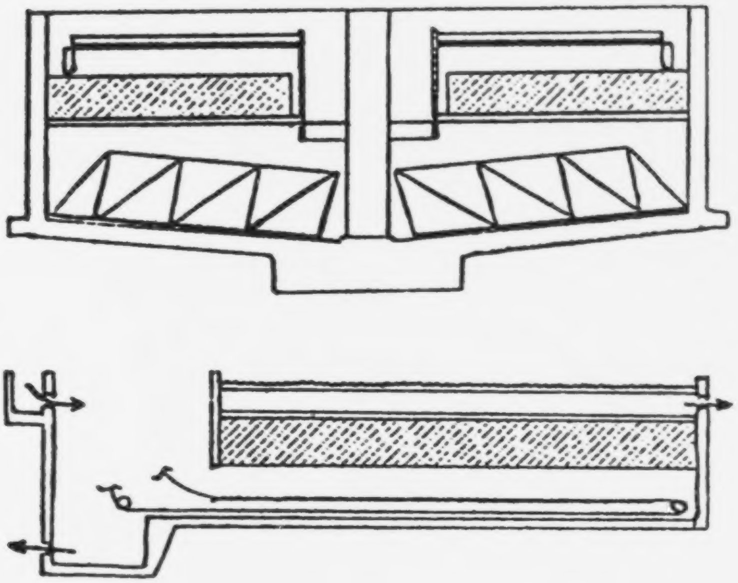
[18] *Short-circuiting. A condition that occurs in tanks or ponds when some of the water or wastewater travels faster than the rest of the flowing water.*



TUBE SETTLERS IN EXISTING CLARIFIER

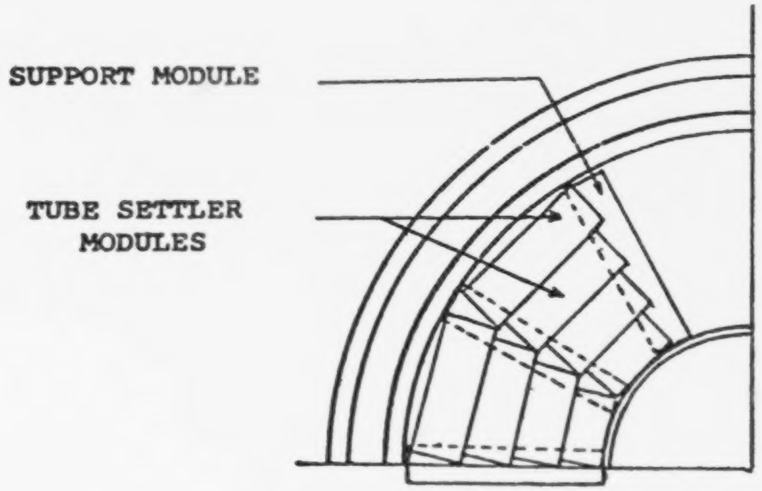

SUPPORT MODULE
TUBE SETTLER MODULES

Fig. 6.50 Plan view of modified clarifier

6.431 Clarifier Efficiency

Clarifier efficiency may be defined as the percent of a pollutant removed by the clarifier. Efficiency should be based upon the analysis of both inlet and outlet samples composited over a 24-hour period. Calculation is as follows:

$$\text{Efficiency, \%} = \frac{\text{In} - \text{Out}}{\text{In}} \times 100\%$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 451.

6.4F List the three common modes of rapid mixing of coagulant chemicals.

6.4G What is tapered flocculation?

6.4H What is an advantage of vertical-flow clarifier units?

6.4I List the four factors that are considered in the design of clarifiers.

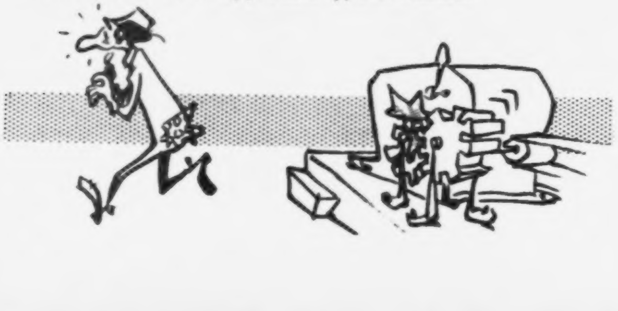
6.4J What happens if the detention time in a clarifier is too short?

6.4K List the possible causes of short-circuiting.

6.44 Safety

6.440 Safety in Handling Coagulant Chemicals

1. Avoid getting inorganic coagulants on the skin or in the eyes. These chemicals are either corrosive or caustic and cause irritation and possibly permanent damage. Areas contacted should be flushed immediately with water. In the case of dry chemicals, attempt to mechanically wipe or brush off as much as possible before flushing.
2. *POLYMERS MIXED WITH WATER ARE EXTREMELY SLIPPERY* and can cause a fall hazard if left unattended on walkways. Spills should be cleaned immediately with generous portions of water.
3. Gases under pressure should be stored in a cool location and secured tightly to a vertical support. Areas should be properly labeled to designate hazard of flammability, corrosiveness or other applicable type of hazard.



6.441 Safety Around Machinery

1. Avoid placing extremities (parts of your body) into any moving part of machinery.
2. Be aware of areas where piping may be subject to high pressure.
3. Be sure all power is turned off and appropriately tagged before working on a piece of machinery for either mechanical or electrical malfunction.

6.442 Other Hazards

1. Be aware of causes for falls. Avoid clutter. Clean grease and oil and polymer spills immediately.
2. Always be aware of a drowning hazard around open basins. Make use of handrails in all work locations. Approach basins through areas which have appropriate walkways. Insure the availability of life preservers in work areas.

6.45 Operation, Start-up and Maintenance

6.450 Start-up Maintenance Inspections

The following represents a general start-up inspection checklist; however, it will also be found meaningful in an overall maintenance format. Because of the diverse nature of industrial wastewater treatment plants and the broad differences from one manufacturer's equipment to another, it is suggested that the manufacturer's specifications be consulted for more in-depth maintenance procedures. For simplicity and to avoid duplication, some items have been grouped under equipment type rather than process stage.

A. General

   1. Determine that all tanks, basins and piping are clean and free of debris.
   2. Insure that all drawings, equipment manufacturer's specifications and operating manuals are complete, up-to-date and available.
   3. Verify that the correct spare parts are on hand.
   4. Insure the proper operation of all Start-Emergency-Stop controls both on site and at the control panel. Check all electrical connections and power supplies.
   5. Insure that all piping and valves are properly installed and adequately braced.

B. Motors and Drives

   1. Insure that all motors and drives are securely fastened. Check bearing supports, shaft alignments to drive motors and belts (for both condition and tightness).
   2. Insure proper lubrication of motors, drives, shafts, chains and bearings according to the manufacturer's specifications.
   3. Verify that motors run at the speeds prescribed and that all voltage requirements are satisfied.
   4. Insure that chains move freely without binding.
   5. Insure that all chain guards are in place.
   6. Insure that motor rotation is correct.

C. Pumps

   1. Piston Pumps. Check ball seatings, packing, shear pin, drive belts and/or hydraulic fluid.

2. Centrifugal Pumps. Check impeller for wear or plugging. Check for prime. Check packing.
3. Positive Displacement Pumps. Check screw and rotor for wear or plugging. Check prime and packing.
4. Diaphragm pumps. Be sure that diaphragm is intact and working properly.

D. Chemical Feed Systems
 1. Insure that all level alarms in tanks are functioning properly.
 2. Insure proper calibration of all flow and metering systems.
 3. Insure that water blenders operate properly and check dilution mixers for proper placement and installation.
 4. Insure proper temperature and pressure for dilution water.
 5. Insure in-line mixers are in place, properly braced with accommodation for proper bypass.

E. Gates for Control of Flow
 1. Insure all gates properly aligned in angles and for travel clearance.
 2. Insure proper lubrication of wheels and rising stems.
 3. Insure proper operation in both automatic and manual modes.

F. Rapid Mix
 1. Inspect impeller condition. Insure that impellers are free from obstruction.
 2. Check motors and drives as per above (B).

G. Flocculators
 1. Check motors and drives as per above (B).
 2. Insure baffles are correctly set and securely anchored.
 3. Insure that drive stuffing box is properly placed and grouted.
 4. Insure that drive bearing and sprocket are complete.
 5. Insure that mixers rotate freely before coupling to the gear drive.
 6. Insure that sump pumps are in place and operational.

H. Clarifiers
 1. Check motors and drives as per above (B).
 2. Insure that all sprockets and shafts are in alignment and free for the rotation of the sludge collectors.
 3. Lube all rails. Run collectors in empty tank (dry) for two hours before allowing the water into the flocculation tank.
 4. Insure all flights are connected to the chain and that all shoes are attached.
 5. Check that all drive sprockets are operational. Insure that shear pins are installed in all sprockets.
 6. Check the operation of limit switches to insure that they stop the motor.
 7. Check cross-collector travel.

I. Scum Collectors
 1. Insure that the collectors and trough are properly secured and aligned.
 2. Insure that the wiper blade on the spiral collectors has proper uniform contact with the breaching plate.

6.541 Actual Start-up

The following constitutes a general pattern to be followed when placing the entire system on-line. Sections may be applied to the start-up of an individual part.

A. Chemical Feed System
 1. Insure proper temperature for dilution waters, if applicable.
 2. Check that proper chemical strengths are set on automatic feeds.
 3. Open all manual valves, as appropriate.
 4. Set proper flow rate.

B. Mixing Tank
 1. Open effluent gates.
 2. Allow tanks to fill.
 3. Start mixers and adjust speed.

C. Flocculation Tanks
 1. Open influent gates.
 2. Turn on and adjust paddle drives.

D. Clarifiers
 1. Turn on cross-collectors and longitudinal collectors.
 2. Start scum collectors.
 3. Allow basins to fill.

6.452 Operational Strategy Checklist

A general procedure for the normal operation of a chemical coagulation-precipitation system is discussed in the following paragraphs.

A. Chemical Feed System
 1. Perform a jar test to determine the proper chemical dosage.
 2. Insure proper chemical dilution.
 3. Set controls for the proper feed rate.
 4. Report in the operating log the amount of chemical used per unit time.

B. Rapid Mixing Tanks
 1. Insure proper mixing speed by observing the floc formed.
 2. Check for scum formation. If scum accumulates in the influent, open the scum gates. If scum is floating in the tanks, adjust the mixer speed. Should the condition persist, open the slide gates and allow it to pass through the effluent.
 3. Only operate mixers when the tank is filled to capacity.
 4. Do not allow mixers to be off for an extended period while material is still in the tank.

C. Flocculation Tanks

1. Adjust agitation so that particles receive just enough so as not to settle.
2. Check to see that chemical is being added if no floc forms (see Section 28.453 on Troubleshooting).
3. Adjust all paddles to the same speed unless:
    a. Sludge formation occurs at one point. Increase the paddle speed for this area.
    b. Coagulant is added at the floc tanks. Increase the tip speed of the mixers immediately preceeding the point of discharge.
    c. Coagulant added in the influent channel. Increase the tip speed of the first mixer.

6.453 Abnormal Operating Procedures and Troubleshooting

D. Clarifiers

1. If possible, all tanks should be kept in operation since the best sedimentation occurs with the greatest amount of the surface area.
2. Sludge control. Level should be kept at a minimum.
3. Never store sludge in the clarifiers. Move it to the thickeners for storage.
4. Scum Removal. Check periodically.
   Skimmer. Clean daily.
   Scum pit. Clean after each pumping.
5. Clean weirs, scum baffles and launders daily.

The following represents a guide to the types of problems an operator should look for with possible causes and solutions.

Problem	**Cause**	**Solution**
Excess scum buildup	Scum collection device	Inspect scum trough, spiral screw and scum pumps.
Too small floc	Improper chemical dosage	Check dosage with jar test.
	Low chemical metering	Adjust metering.
	Chemical feed pump adjusted too low	Adjust feed pumps.
	Paddle speed in flocculators or rapid mix too fast	Decrease paddle speed.
	Short-circuiting	Baffling changes, adjust weir plates or port openings.
	Change in pH	Neutralize pH.
Too large floc, settles too soon	Improper chemical dosage	Check dosage with jar test.
	Metering setting	Check and adjust metering.
	Chemical makeup too strong	Check makeup and adjust feed.
	Too little dilution water	Check and adjust metering of dilution water.
	Paddle speed in rapid mix or flocculator too slow	Increase paddle speed
	Coagulant aid added at wrong point	Optimize point of coagulant aid addition (in rapid mix, before flocculator, in flocculator).
Floating sludge	Sludge collectors not functioning properly	Check motors, chains, drives and belts for smooth operation.
	Sludge pumping system malfunction	Check sludge pumps for operation, pipes for debris. Switch to standby pump.
	Change in influent character or flow rate	Check dosage with jar test and adjust.
	Excess coagulant aid	Check dosage with jar test and adjust.
Loss of solids over effluent weir	See too small floc problem above	
	Improper or misaligned baffling	Adjust baffling at inlet and outlet.
Thin sludge with deep sludge blanket	Cross collectors not functioning	Check motors, drives and chains for cross collectors.
Sludge collector, jerkey operation or inoperable	Broken sprocket, chain link, flight or shear pin	Inspect and repair.
	Sludge blanket too deep	Pump out sludge. May have to drain basin and remove manually.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 451 and 452.

6.4L How should gases under pressure be stored?

6.4M What are some of the causes of falls?

6.4N List the items you would check during the start-up inspection of a chemical feed system.

6.4O List the procedures you would follow for the normal operation of a chemical coagulation-precipitation system.

END OF LESSON 5 OF 6 LESSONS
ON
INDUSTRIAL WASTE TREATMENT

Please work the discussion and review questions before continuing. The question numbering continues from Lesson 4.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 5 of 6 Lessons)

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 4.

28. What is the purpose of chemical coagulation?
29. Why is paddle speed important during flocculation?
30. What happens to inorganic solids used as coagulants if they become moist?
31. Why is the solids loading especially important in the design of clarifiers treating industrial wastes?
32. Why should operators have an understanding of the original design considerations for clarifiers?
33. What is the most effective cure for short-circuiting?
34. What would you do if a dry coagulant chemical came in contact with your skin?

PROBLEM
CAUSE
SOLUTION

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

(Lesson 6 of 6 Lessons)

6.5 ADSORPTION[19] (ACTIVATED CARBON) by John Gonzales

6.50 Principles of Activated Carbon Adsorption

6.500 Purpose of Carbon Adsorption

The purpose of activated carbon adsorption in wastewater treatment plants is to remove organic solutions from the effluent of the treatment plant (Figures 6.51 and 6.52). Removal of the organic pollutants frees effluent from color, taste- and odor-causing pollutants which may remain after preceding wastewater treatment processes. Uses of activated carbon for foul-air scrubbing is discussed in Chapter 1, "Odor Control," *ADVANCED WASTE TREATMENT.*

In areas across the country where fragile environmental systems exist which require substantial tertiary treatment of a plant's effluent, the activated carbon process is considered as an effluent polishing process. The removal of trace amounts of organic material can be accomplished using carbon adsorption. The result is a crystal clear water with no odor and a biochemical oxygen demand in the effluent of almost zero.

6.501 How Does Carbon Adsorption Work?

Activated carbon can remove trace amounts of organic material from effluent by the attraction and accumulation of the particles to the surface of the carbon. This is the definition of adsorption. Particles adhere to the surface of the activated carbon very much like a magnet attracts particles of iron. As wastewater passes through a field of activated carbon, any pollutants or contaminants that can be adsorbed onto the carbon surface will be attracted. Once the molecules of organic material have been attracted to the surface, the activated carbon will continue to accumulate the organic material until it can no longer adsorb any more.

6.502 The Manufacture of Activated Carbon

Activated carbon can be produced from wood, coal, nutshells, bone, petroleum residues or even sawdust. The material utilized to make activated carbon must be a carbonaceous material in order for the material to go through a process of carbonization.

Carbon is activated by drying the raw material and slowly heating it in the absence of air. The result is an activated carbon that can still burn. However, the lower the heating temperature, the better are the volatile substances driven off but extreme heat is required to burn the remaining residue to produce the activated carbon.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 452.

6.5A Why is the activated carbon adsorption process used to treat wastewater?

6.5B What materials may be used to make activated carbon?

6.5C How is activated carbon made?

6.51 The Carbon Adsorption Process

6.510 General Physical Principles

During production of activated carbon, the carbon particles are put into contact with a water vapor or steam and water while the carbon particles are still very hot. The result is a fracturing of the carbon to produce small cracks or fissures within each of the small particles. These fissures are used in the attraction and adsorption process.

Molecules of organic materials which pass by the carbon particles are attracted and held to the surface of the carbon. Some smaller molecules may find their way into the pores or the fissures which were produced during the quenching or cooling cycle of the carbon manufacturing process. Other particles may be trapped on the surface or wedge themselves into the larger part of the fissure opening at the surface of the carbon particle.

6.511 Equipment Necessary for Carbon Adsorption

The most commonly used equipment for carbon adsorption is a pressure tank (Figure 6.53) filled with activated carbon. The standard method of operation is to use an upflow carbon adsorption pressure vessel (Figure 6.54). The reason for an upflow pressure vessel is to allow adequate detention time within the chamber for adsorption of the organic material in the effluent waters. A pressurized upflow carbon contact chamber (Figure 6.55) will help eliminate short-circuiting that is common in downflow pressure vessels. Also, flow is easily regulated in upflow and it is possible to fill the carbon contactors with new granular carbon even while flow is continuing to the vessel. Although pressurized contact chambers are the most common, both upflow and downflow gravity activated carbon contactors are used to treat industrial wastewaters.

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[19] *Adsorption (add-SORP-shun). The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.*

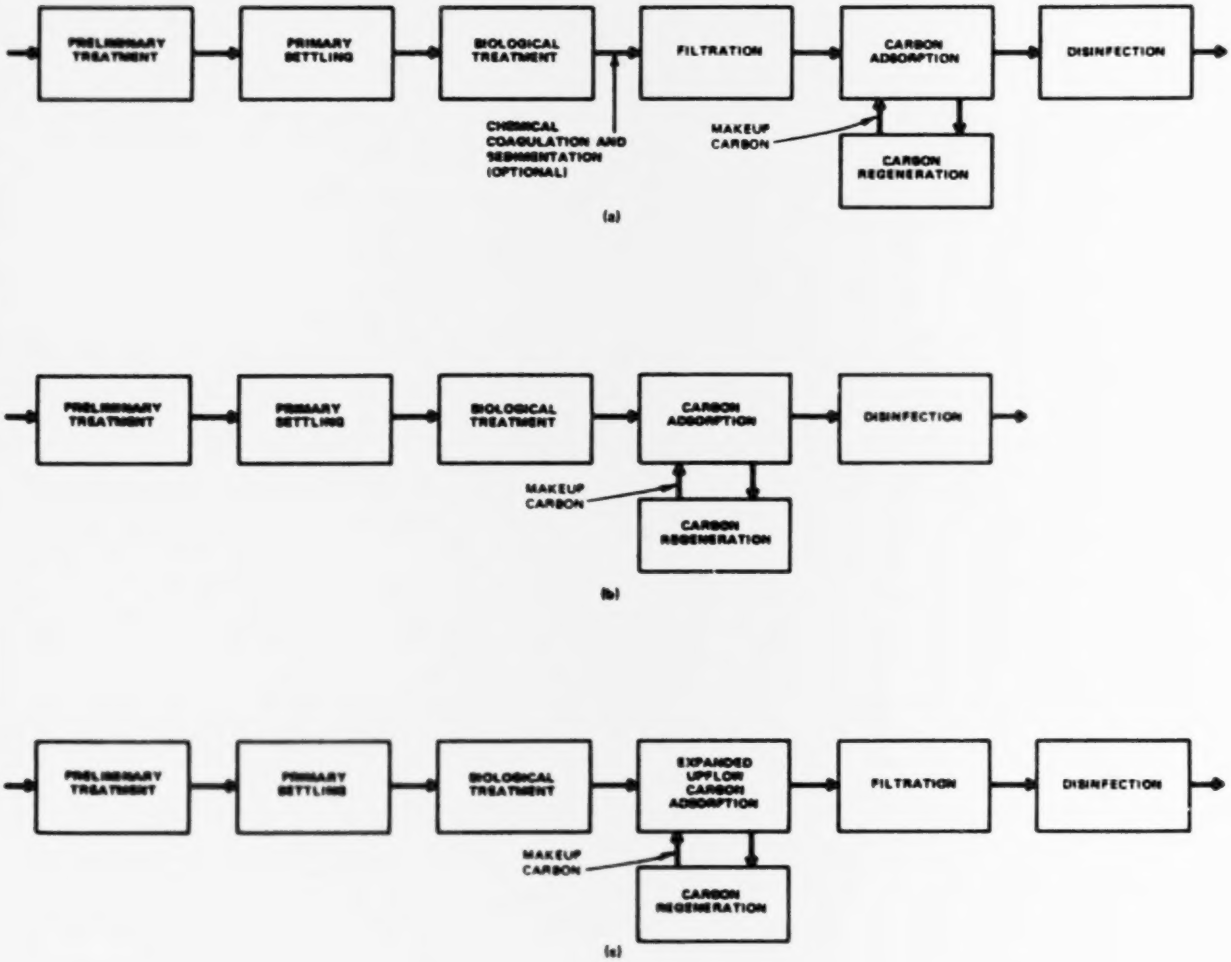

PRELIMINARY TREATMENT
PRIMARY SETTLING
BIOLOGICAL TREATMENT
FILTRATION
CARBON ADSORPTION
DISINFECTION
CHEMICAL COAGULATION AND SEDIMENTATION (OPTIONAL)
MAKEUP CARBON
CARBON REGENERATION
(a)
PRELIMINARY TREATMENT
PRIMARY SETTLING
BIOLOGICAL TREATMENT
CARBON ADSORPTION
DISINFECTION
MAKEUP CARBON
CARBON REGENERATION
(b)
PRELIMINARY TREATMENT
PRIMARY SETTLING
BIOLOGICAL TREATMENT
EXPANDED UPFLOW CARBON ADSORPTION
FILTRATION
DISINFECTION
MAKEUP CARBON
CARBON REGENERATION
(c)

Fig. 6.51 Typical treatment schemes using carbon adsorption as a tertiary step

(Source: Process Design Manual for Carbon Adsorption, Technology Transfer, U.S. Environmental Protection Agency.)

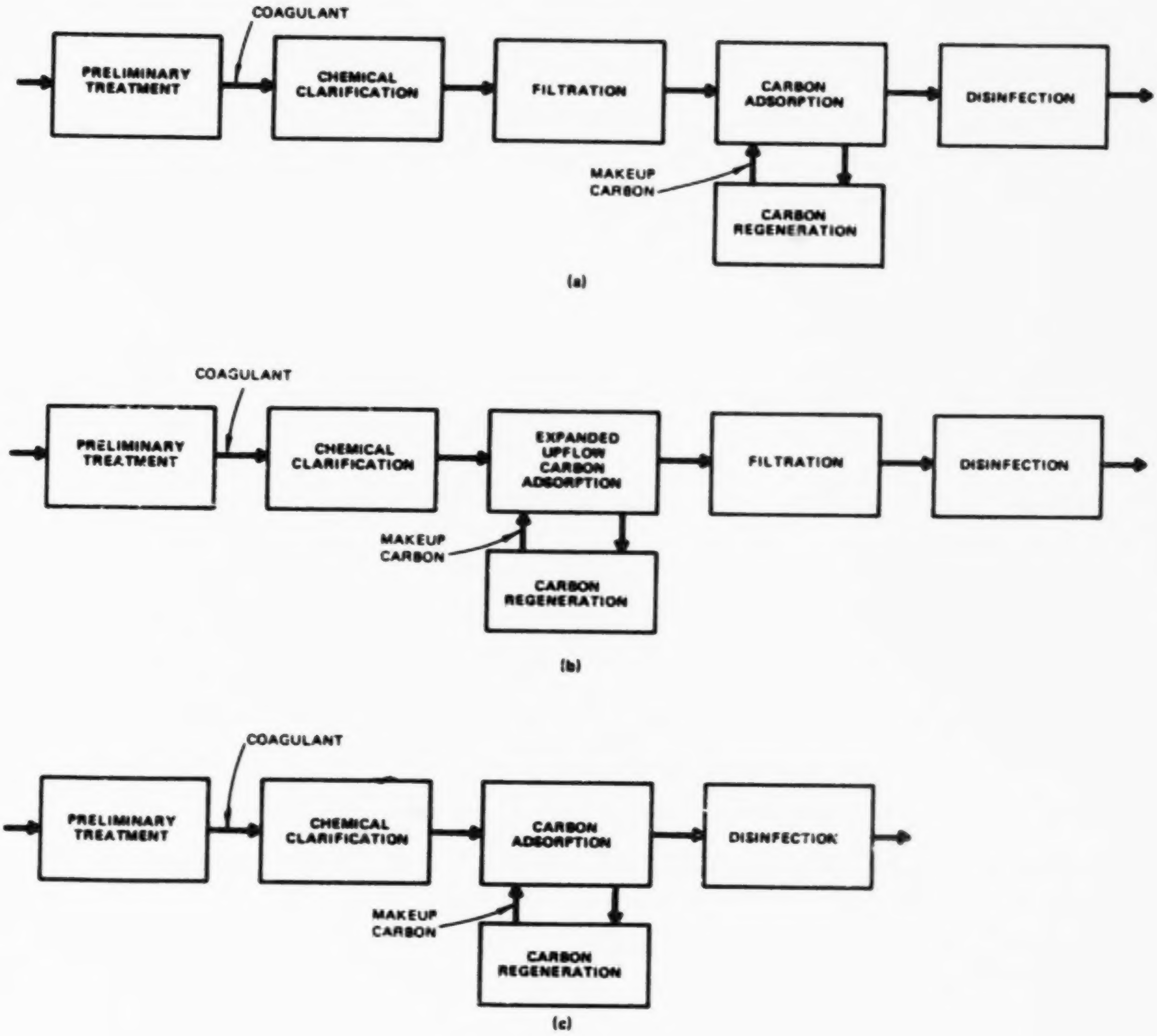

COAGULANT
PRELIMINARY TREATMENT
CHEMICAL CLARIFICATION
FILTRATION
CARBON ADSORPTION
DISINFECTION
MAKEUP CARBON
CARBON REGENERATION
(a)
COAGULANT
PRELIMINARY TREATMENT
CHEMICAL CLARIFICATION
EXPANDED UPFLOW CARBON ADSORPTION
FILTRATION
DISINFECTION
MAKEUP CARBON
CARBON REGENERATION
(b)
COAGULANT
PRELIMINARY TREATMENT
CHEMICAL CLARIFICATION
CARBON ADSORPTION
DISINFECTION
MAKEUP CARBON
CARBON REGENERATION
(c)

Fig. 6.52 Typical physical-chemical treatment schemes

(Source: Process Design Manual for Carbon Adsorption, Technology Transfer, U.S. Environmental Protection Agency.)

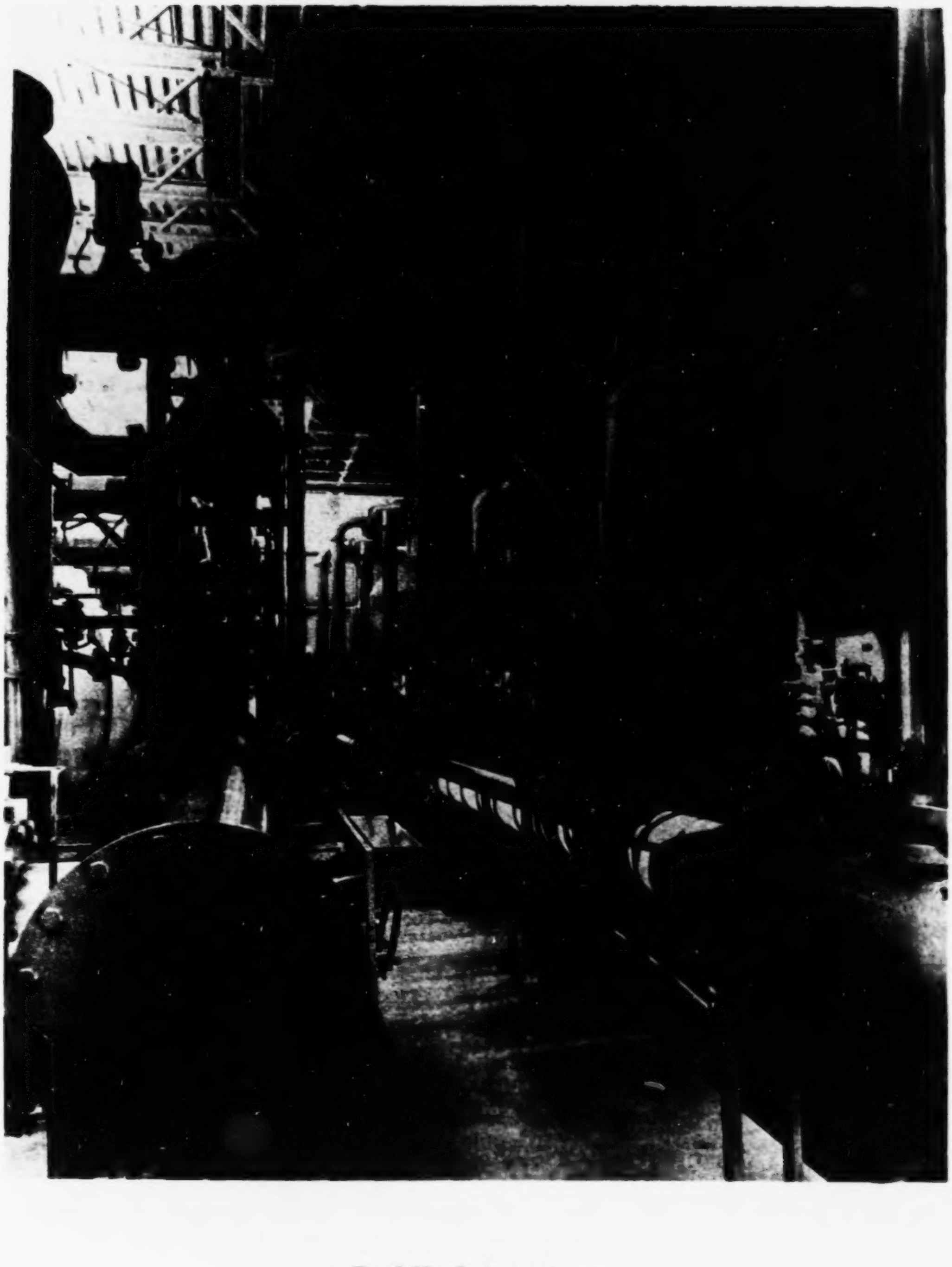


Fig. 6.53 Carbon columns

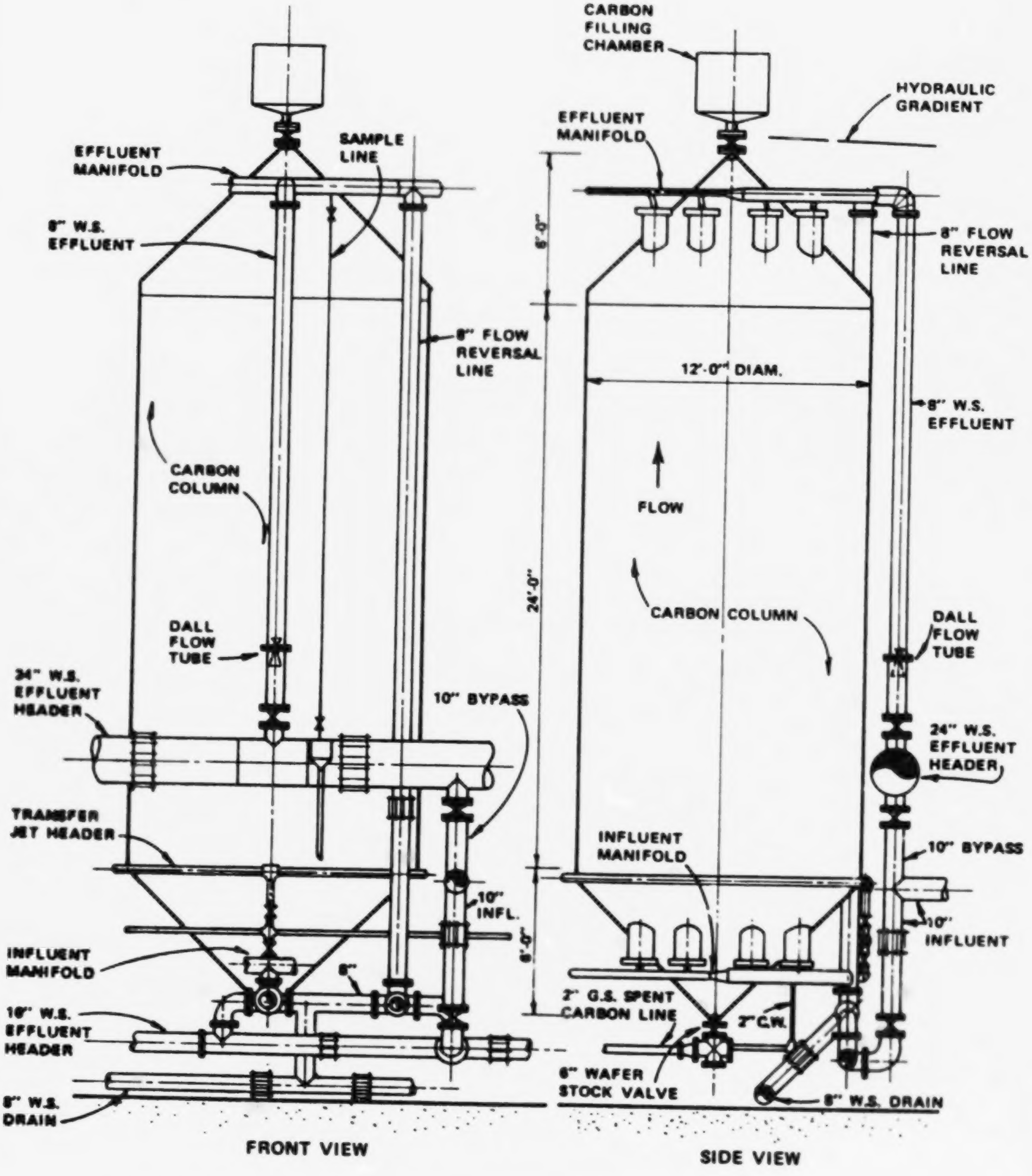

EFFLUENT MANIFOLD
SAMPLE LINE
8" W.S. EFFLUENT
8" FLOW REVERSAL LINE
CARBON COLUMN
DALL FLOW TUBE
24" W.S. EFFLUENT HEADER
10" BYPASS
TRANSFER JET HEADER
10" INFL.
INFLUENT MANIFOLD
6"
10" W.S. EFFLUENT HEADER
8" W.S. DRAIN
FRONT VIEW
CARBON FILLING CHAMBER
HYDRAULIC GRADIENT
EFFLUENT MANIFOLD
6'-0"
8" FLOW REVERSAL LINE
12'-0" DIAM.
8" W.S. EFFLUENT
FLOW
24'-0"
CARBON COLUMN
DALL FLOW TUBE
24" W.S. EFFLUENT HEADER
INFLUENT MANIFOLD
10" BYPASS
10" INFLUENT
6'-0"
2" G.S. SPENT CARBON LINE
2" C.W.
6" WAFER STOCK VALVE
8" W.S. DRAIN
SIDE VIEW

Fig. 6.54 Upflow countercurrent carbon column Orange County, California

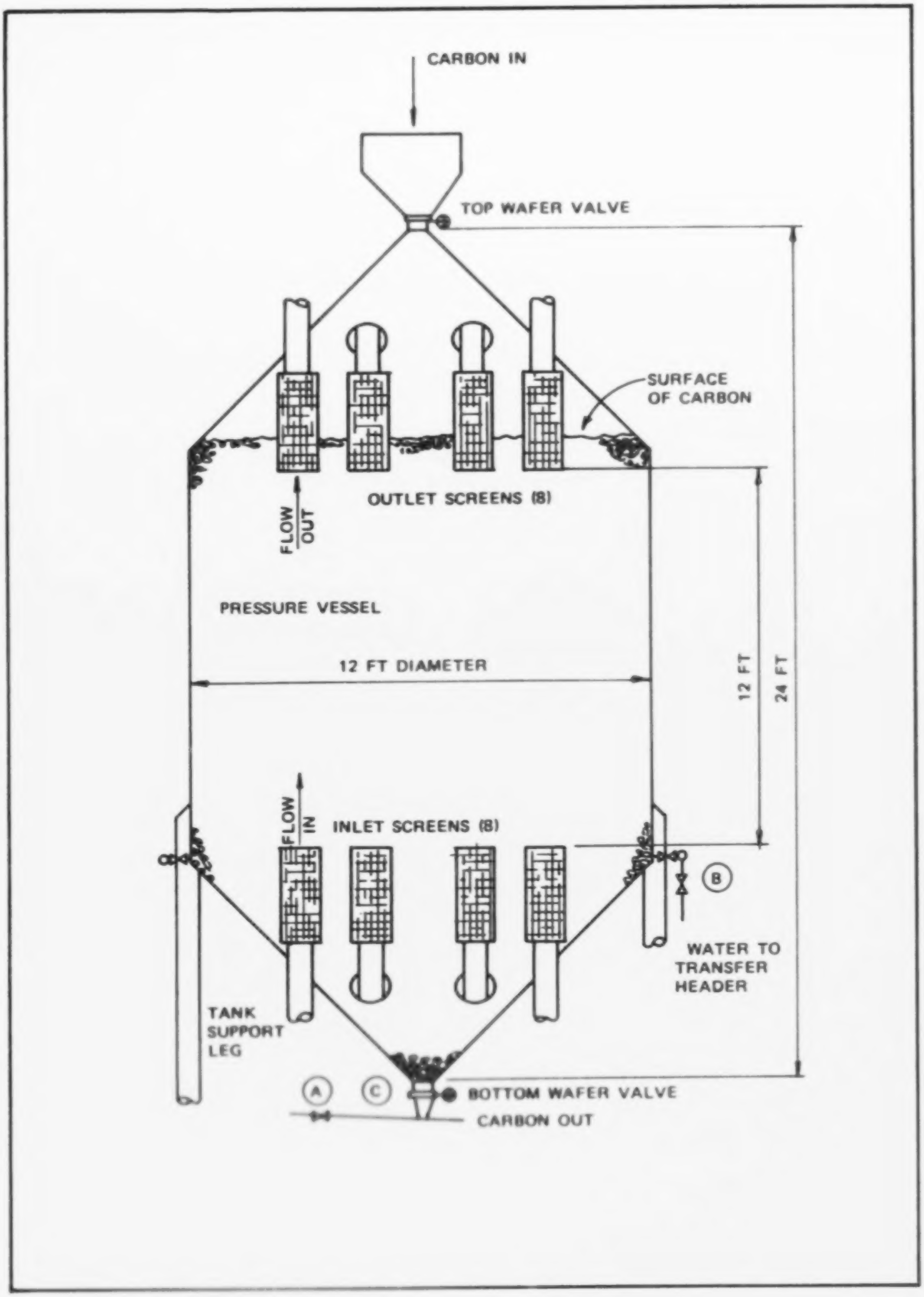

CARBON IN
TOP WAFER VALVE
SURFACE OF CARBON
OUTLET SCREENS (8)
FLOW OUT
PRESSURE VESSEL
12 FT DIAMETER
12 FT
24 FT
FLOW IN
INLET SCREENS (8)
B
WATER TO TRANSFER HEADER
TANK SUPPORT LEG
A
C
BOTTOM WAFER VALVE
CARBON OUT

Fig. 6.55 Section through carbon column

6.512 Pre-Start-Up

1. Proper Quantities of Activated Carbon. To determine the proper quantity of activated carbon, you can assume that the desired detention time in the carbon containers is 30 minutes. The amount of carbon provided in each carbon column should be such that flow through the carbon would take 30 minutes to complete. Check the levels of carbon by measuring from the top of the carbon column to the surface of the granular carbon within the pressure vessel. The volume of the carbon up to the measurement should be calculated. This volume should be increased if the detention time through the calculated volume at the desired flow rate is less than 30 minutes.

2. Activated Carbon Loading Equipment. Proper piping and measuring equipment are necessary in order to fill carbon columns to the proper level within the pressure container. Equipment for loading activated carbon includes dust control equipment which will be discussed later in this chapter and defining equipment for washing the carbon before it enters the carbon column reactors.

3. Valves and Piping. The standard schematic diagram illustrating piping is shown in Figure 6.56. Valving and piping in and around a carbon container must be flexible. Three-way valves are usually installed in order to provide both the upflow conditions necessary for the activated carbon treatment, and also to allow for backwashing of filter screens. Before placing the carbon reactors on line, the valving should be checked to ensure that the flow direction is correct for the operation desired. The operator should know where each pipe leads and the direction of flow through the pipe that is desired.

4. Carbon Column Reactors. The carbon column reactors are also known as the pressure containers which contain the carbon for the adsorption process. The tank is normally 8 to 15 feet (2.4 to 4.5 m) in diameter and can be 15 to 28 feet (4.5 to 8.4 m) tall. Inside the containers are screens that prevent carbon from flowing in either direction with the water. The screens keep the carbon within the pressure vessel.

The carbon column reactors are lined with an epoxy or resin to prevent corrosion from the contact of the carbon with the surface of the vessel. Wet carbon can be very corrosive and the lining protects the steel used in the manufacturing process of the pressure container.

6.513 General Operating Procedures

1. Counter-Current Flow Principle. The most common form of operation of a carbon reactor is an upflow condition. Effluent enters the bottom of the reactor and flows out through the top. The counter-current principle is the process where flow enters the bottom of the carbon column and new or regenerated carbon is added to the top of the container. This allows the oldest carbon to contact the wastewater first and the newest or more virgin carbon will make contact with the effluent last. In this manner, the wastewater is polished as it flows up through the carbon column.

   The counter-current flow principle allows the spent or the most used carbon to be pulled off from the bottom of the pressure vessel for regeneration. In this way, a regeneration cycle of burning off the adsorped particles is not wasted on fresh carbon.

2. The Adsorption Mechanism. Adsorption of organic material in wastewater takes place in three steps. The first step is contact of the liquid to the exterior surface of the carbon. The second step is disbursement of the liquid within the pore space of the activated carbon. The third step is the actual capture of the organic molecules within the pore and capillary structures of the fissures formed in the manufacturing process.

3. Influent and Effluent Piping (Figures 6.57, 6.58 and 6.59). The influent piping around a carbon column reactor is at the bottom of the pressure vessel. Valves are usually located at the bottom of the vessel to allow the normal upflow conditions through the carbon reactor. The valve allows flow to enter at an equal basis into ports which open up and are protected by screens within the container itself. In this manner, a uniform flow is usually achieved through the carbon for proper adsorption.

   The effluent piping of a carbon column reactor is usually located at the top of the container. As with the influent piping, screens are located on the ends of several ports which discharge effluent from the top of the container. Uniform flow is achieved throughout the vessel so that short-circuiting is prevented by having the number of ports in the bottom as well as the top or effluent side of the carbon column.

   The piping is versatile in that flow can be up or down through the carbon column (Fig. 6.60). In this manner, the screens which hold the carbon within the vessel can be backwashed to prevent clogging with carbon fines or the small particles of carbon that adhere to the surface of the screens.

6.514 Placing Carbon Adsorption Units into Operation

1. Flow into Bottom of Carbon Column Reactor. The first step in placing a carbon column into operation is to adjust the valving at the bottom of the column so that effluent from either filtration units or other treatment units which precede the carbon columns will enter the bottom of the reactor. Three-way valves must be aligned so that wastewater will flow through the bottom of the carbon container and out the top of the final effluent receiving station.

2. Adjusting Flow Rate Through Adsorption Reactors. A single valve is usually found on most carbon column reactors. This control valve allows the operator to set the desired gallons-per-minute flow rate through the carbon so that proper adsorption can take place. After the operator has opened the bottom valves to allow flow into the bottom of the carbon column, the flow control valve should be adjusted until the exact flow rate desired is flowing through the carbon and out to the final effluent station.

3. Head Loss Measurements. There is a head loss or loss of pressure between the bottom of a carbon column and the top or effluent side of the container. This head loss is expected since the wastewater must pass through carbon and thereby create a pressure drop or head loss. When head losses are too high (operator must check operations manual supplied by consulting engineer to determine the optimum head loss), backflushing of screens must take place in order to cut down the pressure drop. Gages are located both at the top and bottom of carbon columns, as well as in the control room. The gages are used to help the operator determine the head loss readings so as to know when a backwash cycle must take place. Carbon column screens are backwashed at least once every eight-hour shift.

4. Sampling Effluent to Determine Amount of Carbon Fines. To determine whether the screens in the carbon column reactors are doing an efficient job, sample a portion of the effluent from the top of a carbon column reactor. The

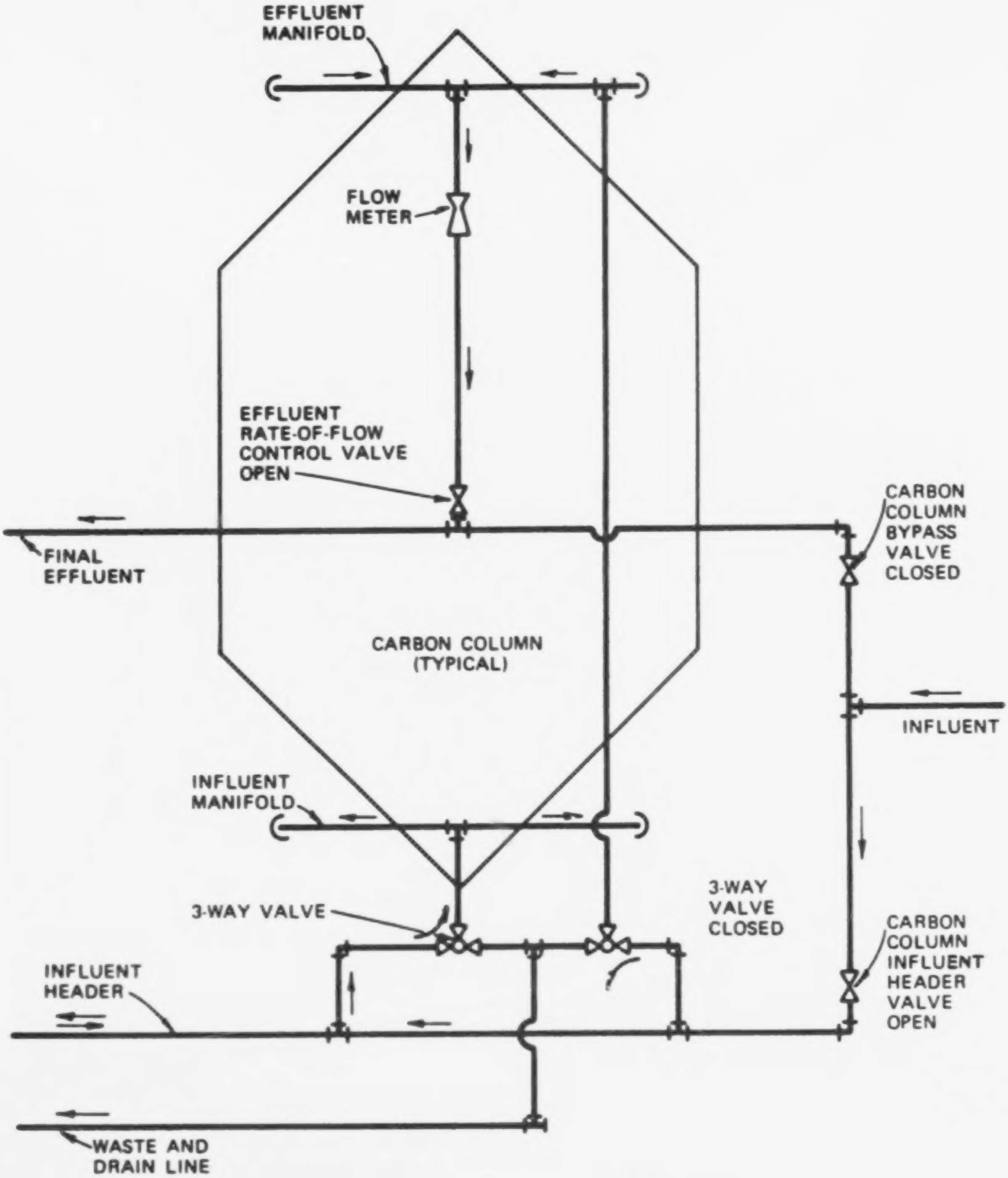

EFFLUENT MANIFOLD
FLOW METER
EFFLUENT RATE-OF-FLOW CONTROL VALVE OPEN
CARBON COLUMN BYPASS VALVE CLOSED
FINAL EFFLUENT
CARBON COLUMN (TYPICAL)
INFLUENT
INFLUENT MANIFOLD
3-WAY VALVE
3-WAY VALVE CLOSED
CARBON COLUMN INFLUENT HEADER VALVE OPEN
INFLUENT HEADER
WASTE AND DRAIN LINE

Fig. 6.56 Upflow carbon column schematic, normal operation Orange County, California

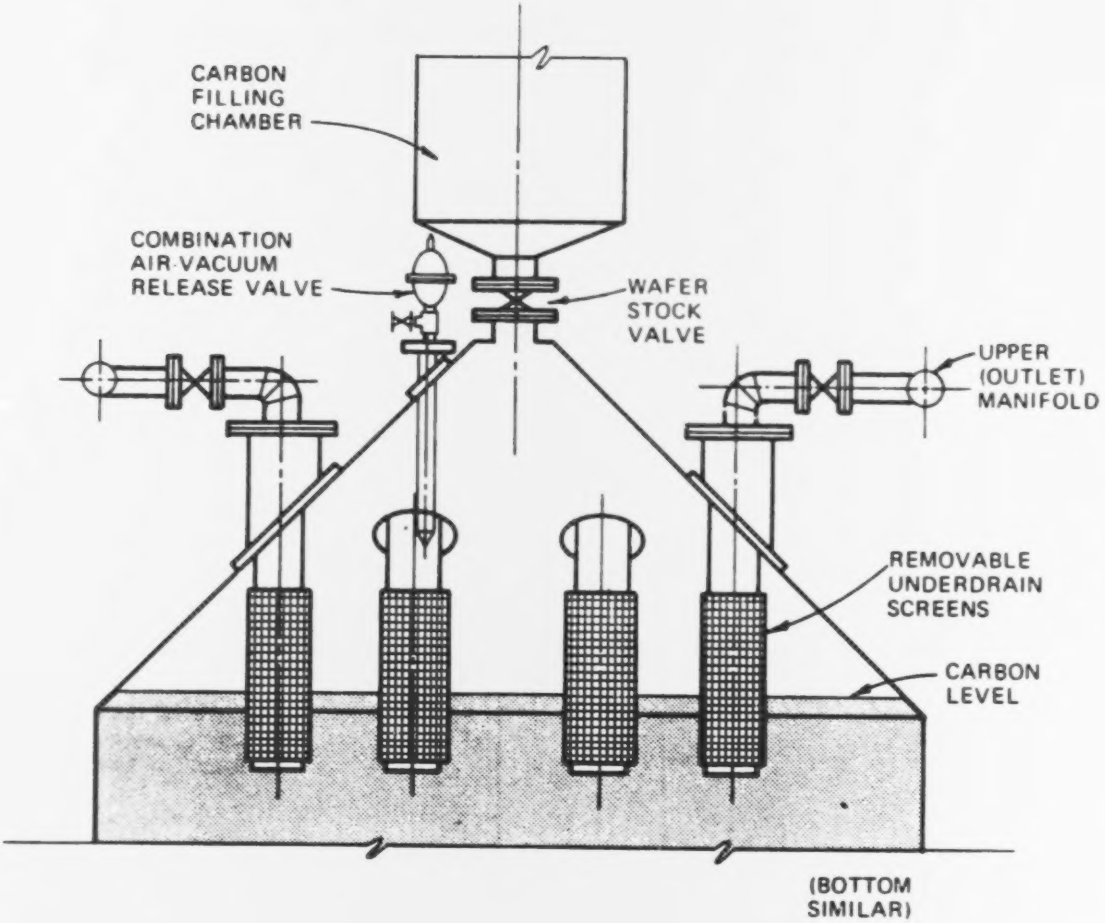
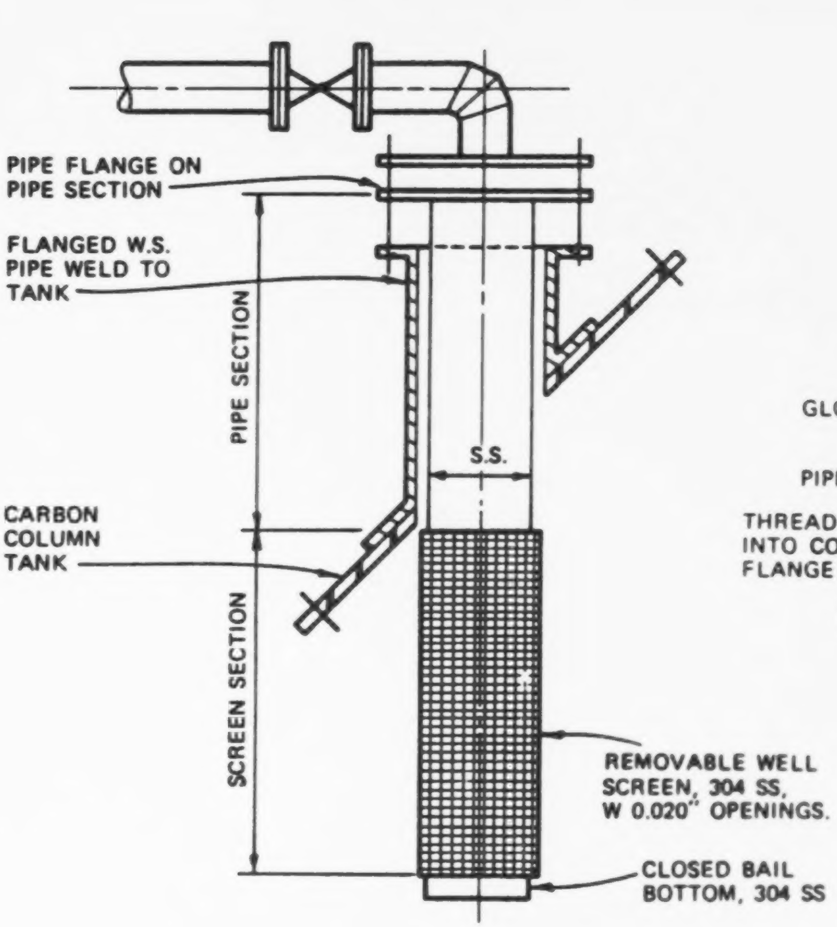

CARBON FILLING CHAMBER
COMBINATION AIR-VACUUM RELEASE VALVE
WAFER STOCK VALVE
UPPER (OUTLET) MANIFOLD
REMOVABLE UNDERDRAIN SCREENS
CARBON LEVEL
(BOTTOM SIMILAR)

Fig. 6.57 Section through top underdrain Orange County, California


PIPE FLANGE ON
PIPE SECTION
FLANGED W.S.
PIPE WELD TO
TANK
PIPE SECTION
S.S.
CARBON
COLUMN
TANK
SCREEN SECTION
REMOVABLE WELL
SCREEN, 304 SS,
W 0.020" OPENINGS.
CLOSED BAIL
BOTTOM, 304 SS

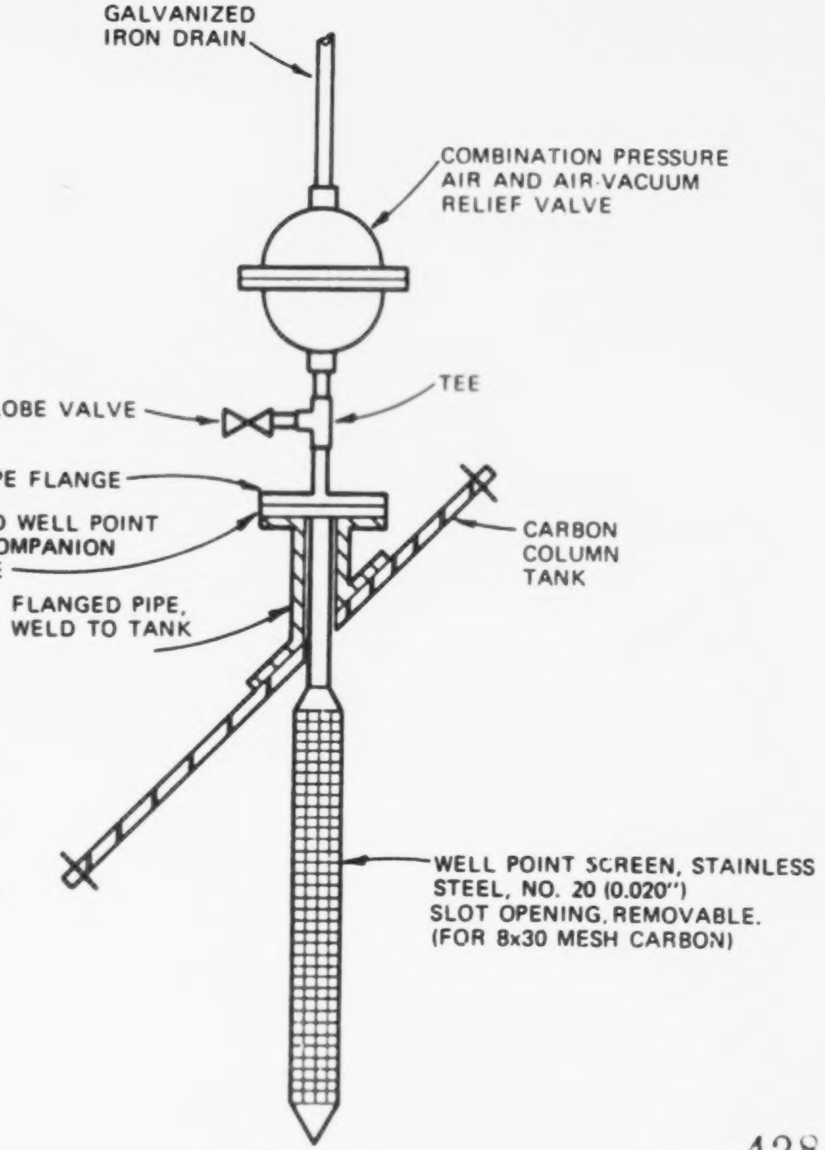

GALVANIZED
IRON DRAIN
COMBINATION PRESSURE
AIR AND AIR-VACUUM
RELIEF VALVE
GLOBE VALVE
TEE
PIPE FLANGE
THREAD WELL POINT
INTO COMPANION
FLANGE
CARBON
COLUMN
TANK
FLANGED PIPE,
WELD TO TANK
WELL POINT SCREEN, STAINLESS
STEEL, NO. 20 (0.020")
SLOT OPENING, REMOVABLE.
(FOR 8x30 MESH CARBON)

Fig. 6.58 Top and bottom underdrains Orange County, California

Fig. 6.59 Air-vacuum relief valve detail

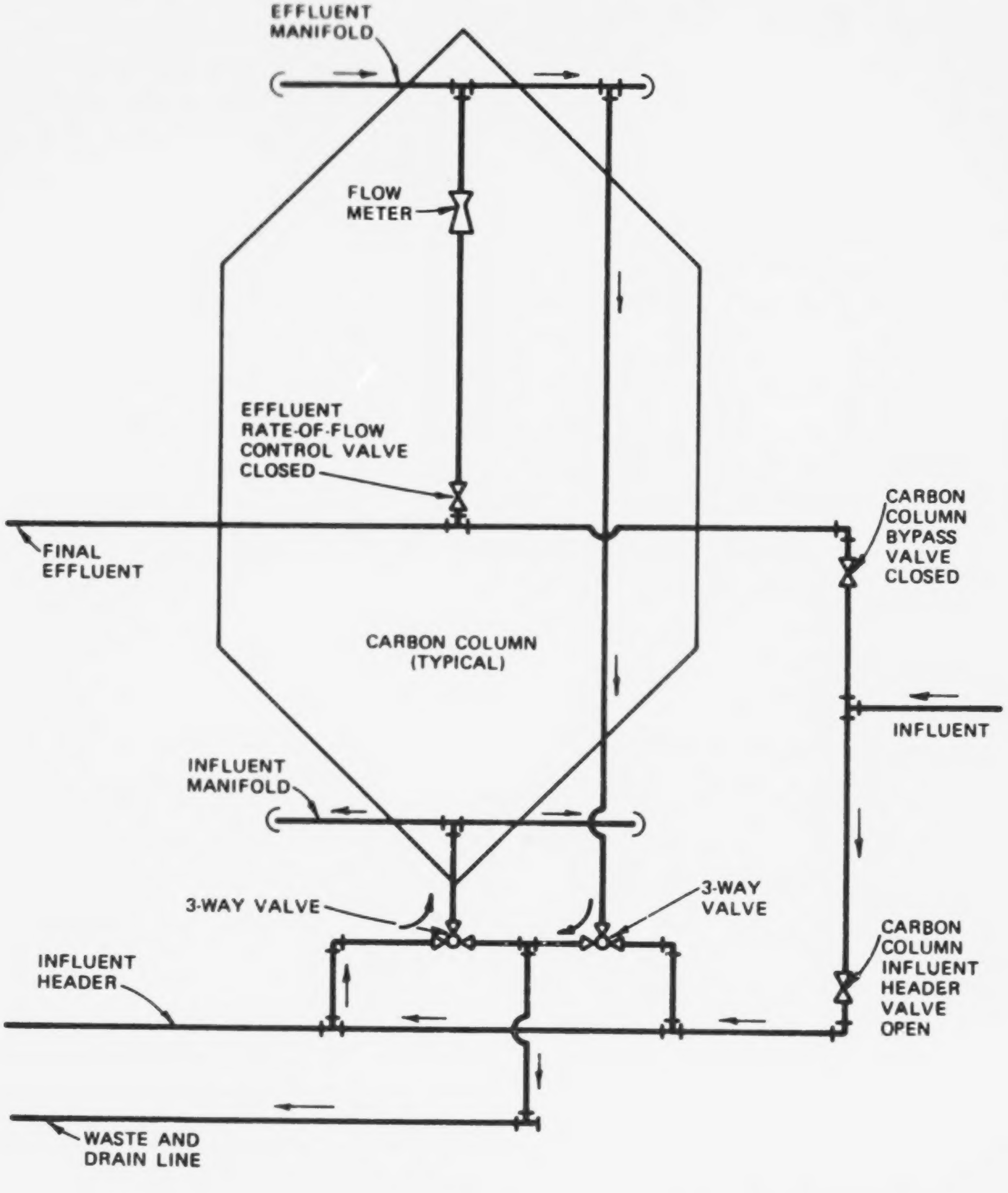
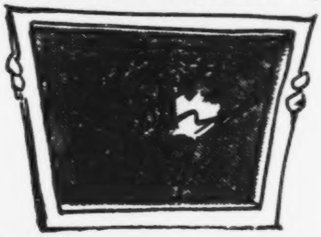

EFFLUENT MANIFOLD
FLOW METER
EFFLUENT RATE-OF-FLOW CONTROL VALVE CLOSED
CARBON COLUMN BYPASS VALVE CLOSED
FINAL EFFLUENT
CARBON COLUMN (TYPICAL)
INFLUENT
INFLUENT MANIFOLD
3-WAY VALVE
3-WAY VALVE
CARBON COLUMN INFLUENT HEADER VALVE OPEN
INFLUENT HEADER
WASTE AND DRAIN LINE

Fig. 6.60 Upflow carbon column schematic, upflow to waste (Used after adding carbon to columns to flush out lines) Orange County, California

effluent should be clear with relatively few specks of carbon in the sample. If excessive carbon fines are found, the operator can assume that perhaps the carbon is rubbing too drastically against the screens causing fine particles to break off and flow out in the effluent or that a hole exists in one of the screens allowing substantial amounts of carbon to flow out in the effluent. A daily check on the relative amount of carbon fines found in the effluent from the carbon column reactors is necessary. The carbon fines in many treatment plants are considered as suspended solids and a reduction in the amount of carbon fines will help reduce the suspended solids that must be reported to regulatory agencies.



6.515 Operational Procedures

1. Routine Backflushing of Fine-mesh Screens to Reduce Head Losses through Carbon Reactors (Figures 6.61). The screens on each carbon column reactor should be backflushed at least once during each eight-hour shift. This will help reduce the amount of carbon fines found in the effluent as well as reduce head losses through the activated carbon treatment.

   If a carbon reactor requires an abnormally high number of backflushings during a shift, the operator should check the instruments and prepare the reactor for an inspection to determine if any damage has taken place inside the vessel. Backflushing and downflow will help eliminate air pockets within the carbon column reactors to prevent short-circuiting and a loss of efficiency in removal of organics.

2. Daily Check for COD Removal Efficiencies. Daily sampling and analysis are important to determine the efficiency of the carbon adsorption process. Chemical oxygen demand (COD) tests are standard and must be performed daily to determine the effectiveness of the carbon adsorption on the removal of organics.

   With properly regenerated activiated carbon and appropriate flow rates and loading conditions, the carbon process will efficiently remove a substantial percentage of the chemical oxygen demand from the effluent. If the removal efficiencies for any carbon column are lower than normal, regeneration or addition of new carbon may be required in order to bring the COD removal efficiencies back to proper levels. The COD removal also depends on flow rates and detention times within the carbon column reactors.

   In order to best understand the operation of each carbon column reactor, a chemical oxygen demand test should be performed daily on effluent from each carbon column reactor. The COD test will help determine if any problems are developing in any of the carbon columns. The problems, if detected early enough, can be corrected before effluent quality is below effluent standards.

3. Turbidity Measurements. Although effluent from a carbon column reactor will usually be very clear and free from color, a daily turbidity measurement is important as a check on the operating efficiency. A turbidimeter should be used to determine whether excess carbon fines are causing high turbidity in the effluent. The turbidimeter can also be used to indicate whether color is efficiently being removed by the activated carbon process.

4. Checks on Various Carbon Column Reactors to Determine Level of Carbon Remaining in Reactor. The operator should check at least weekly to determine whether an adequate amount of carbon remains in each of the carbon column reactors. If additional carbon is needed, make-up or virgin carbon should be added to achieve the proper detention time and ratio of pounds of carbon to chemical oxygen demand removed. The operator should check the operations and maintenance manual provided by the consulting engineer to assess the exact carbon level desired for each of the reactors. The weekly check on the level of carbon will make sure that enough activated carbon is in contact with the wastewater to do an adequate job in removing organics.

5. Troubleshooting. Each day the operator should troubleshoot to determine if any abnormal or unusual conditions may exist that could cause trouble in the activated carbon treatment process. The troubleshooting includes a) checking head losses for abnormally high head losses through the reactors; b) checking for excessive carbon fines in the effluent from the carbon treatment process; c) backflushing the carbon reactors each shift; d) checking turbidity of effluent from the carbon adsorption process; e) checking valving configuration to assure flow direction is correct and the right valves are open or closed; f) checking flow rate through carbon column for proper detention time and adequacy of activated carbon adsorption.

   1) Shut off flow at base of carbon column reactor. If it becomes necessary to shut down the carbon adsorption operation, the operator must shut off the flow into the carbon column reactor by closing the valve at the bottom of the pressure vessel. If all processes except the activated carbon adsorption process are to continue operation, the operator must be certain to turn the three-way valves properly so as to redirect the flow from various preceding processes to other areas besides the carbon adsorption process.

   2) By-pass carbon adsorption units. The valving arrangement is flexible so that if desired, the operator can direct flow to other units besides the carbon column reactors (Figure 6.62). The operator can shut off the carbon column without losing the pressure in the vessel. This can be accomplished by shutting off the bottom valves as well as the effluent flow regulating valve to maintain the liquid within the carbon column vessel. Keep the carbon columns pressurized if the shutdown is for only a brief period. However, if the shutdown of the carbon adsorption process is for a prolonged period of time, the operator should turn the bottom three-way valve so that the carbon column will drain, allowing the activated carbon to dry.

   3) Notification of regulatory agency. If carbon adsorption processes must be shut down, the operator must notify supervisors and/or the regulatory agency. If standards are strict on effluent from the treatment plant, so that activated carbon is required in order to meet standards, any deviation from the standard flow through the carbon column reactors will result in a violation of the discharge limitations. The regulatory agency must be notified so that emergency procedures can be implemented if necessary.

Some treatment plants have a storage reservoir available that can be used if final treatment processes must be shut down. Water stored in these reservoirs should be brought back through the processes for final treatment prior to discharge to any lake or stream which requires the strict standards.

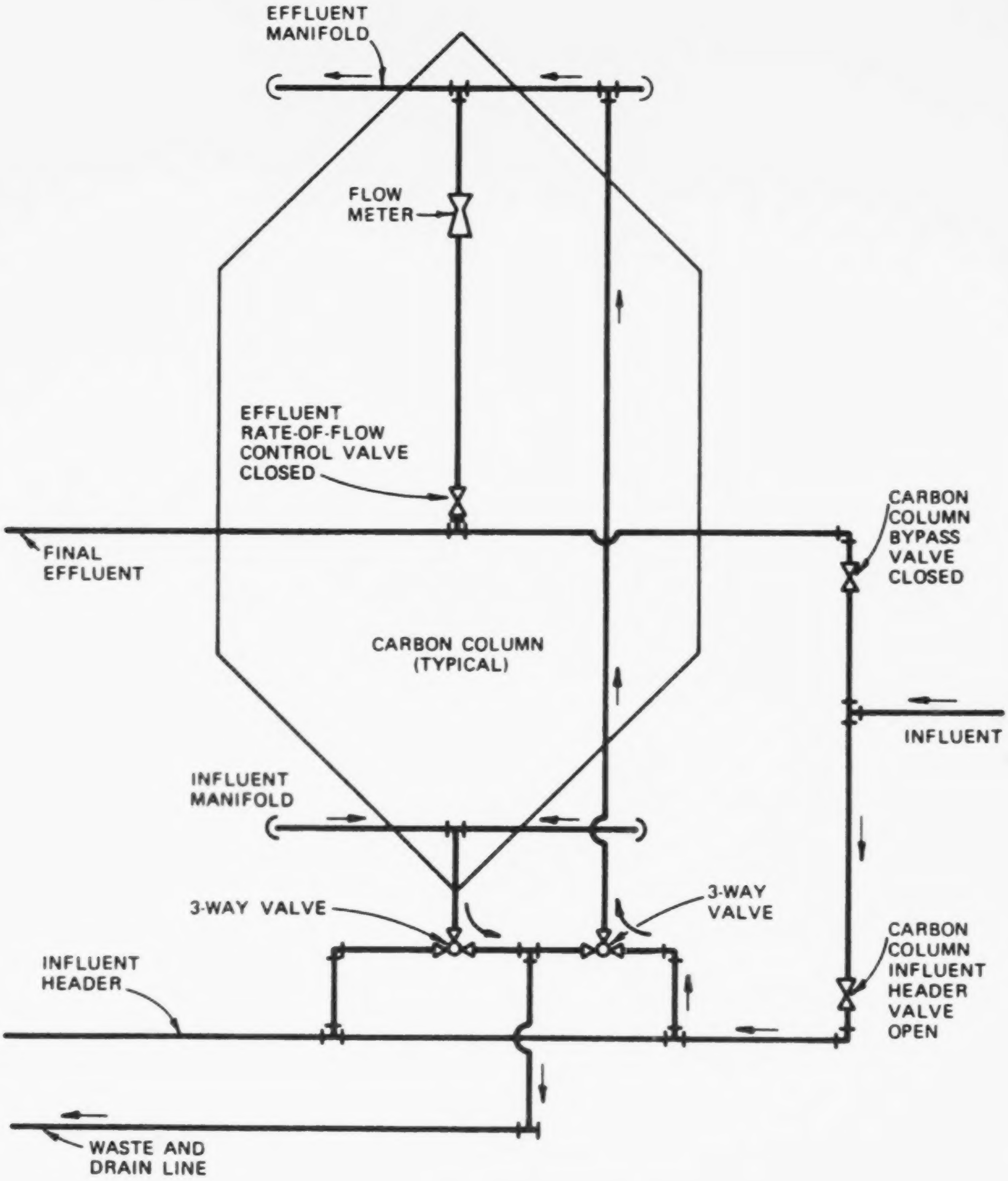

EFFLUENT MANIFOLD
FLOW METER
EFFLUENT RATE-OF-FLOW CONTROL VALVE CLOSED
CARBON COLUMN BYPASS VALVE CLOSED
FINAL EFFLUENT
CARBON COLUMN (TYPICAL)
INFLUENT
INFLUENT MANIFOLD
3-WAY VALVE
3-WAY VALVE
CARBON COLUMN INFLUENT HEADER VALVE OPEN
INFLUENT HEADER
WASTE AND DRAIN LINE

Fig. 6.61 Upflow carbon column schematic - reverse flow
(Used to flush top screens)
Orange County, California

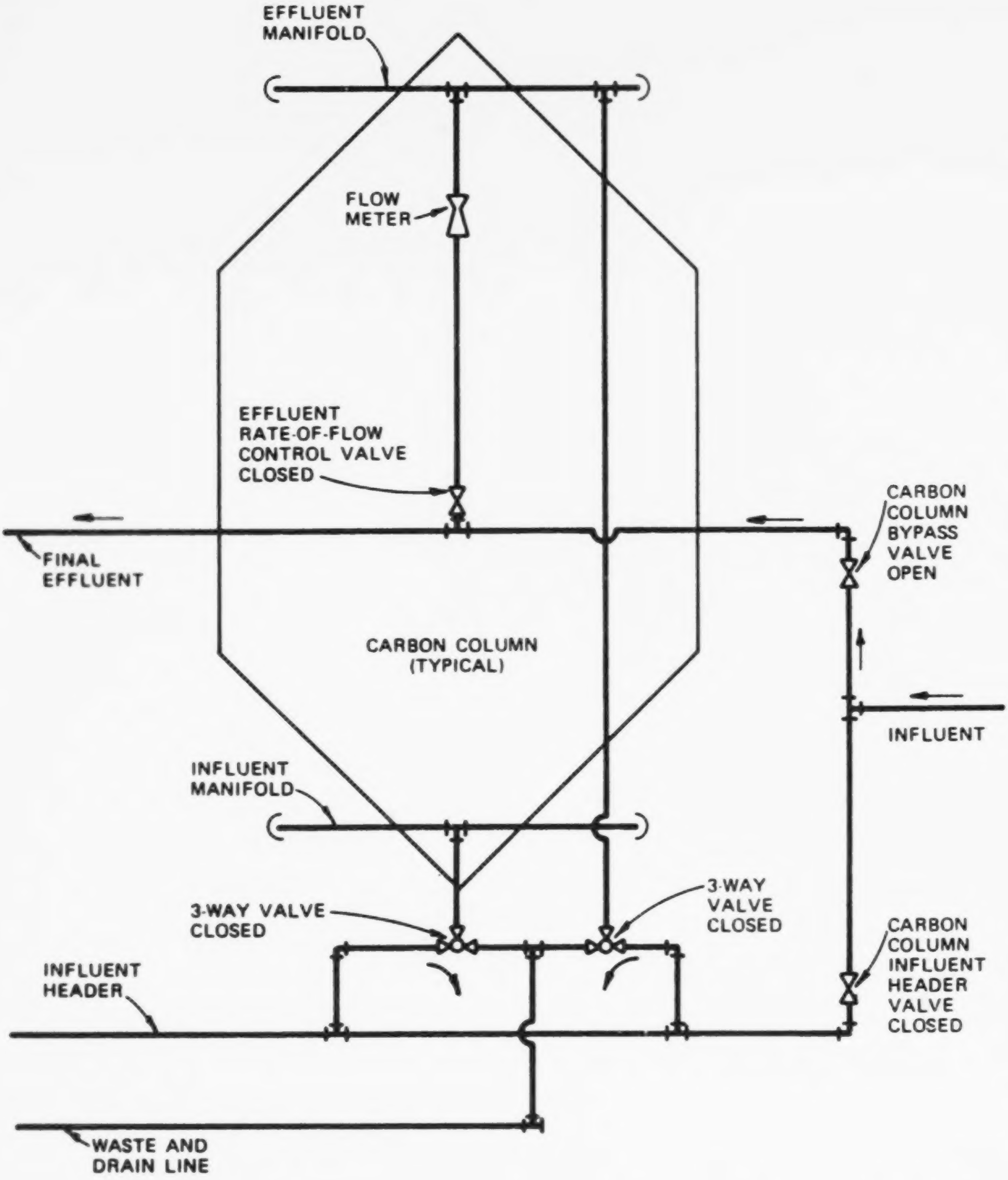

EFFLUENT MANIFOLD
FLOW METER
EFFLUENT RATE-OF-FLOW CONTROL VALVE CLOSED
FINAL EFFLUENT
CARBON COLUMN BYPASS VALVE OPEN
CARBON COLUMN (TYPICAL)
INFLUENT
INFLUENT MANIFOLD
3-WAY VALVE CLOSED
3-WAY VALVE CLOSED
INFLUENT HEADER
CARBON COLUMN INFLUENT HEADER VALVE CLOSED
WASTE AND DRAIN LINE

Fig. 6.62 Upflow carbon column schematic, by-passing carbon column, Orange County, California

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 452.

6.5D What is the desired detention time in an activated carbon pressure vessel?

6.5E Why are three-way valves used in activated carbon piping?

6.5F How is activated carbon kept in the pressure vessel?

6.5G What is the counter-current flow principle?

6.52 Activated Carbon Regeneration

6.520 Purpose for Regeneration of Activated Carbon

As described previously in this chapter, activated carbon is produced by heating carbonaceous material to a high temperature and using water to help form the pore structure necessary for the adsorption process. Regeneration of activated carbon is a process whereby the pores and the surface of the carbon are cleansed of the molecular organic material which has been adsorbed on the surface.

Activated carbon must be regenerated after the carbon has adsorbed all of the molecular organic material that can be adsorbed on the surface and within the pore structure. The purpose of the regeneration process is to drive off the molecular organic material and to allow a clean surface to be readied for additional adsorption of organic material. The most common method for regeneration of activated carbon is through heat treatment in a multiple hearth furnace or a rotary kiln. The carbon undergoes high heat up to 1750 degrees Fahrenheit (950°C) and steam is added for cleansing the carbon of the adsorbed material.

6.521 General Procedure for Reactivation

The general procedure for reactivation of activated carbon is to pull spent carbon from the bottom of carbon column reactors into dewatering bins (Figure 6.63). The carbon is allowed to sit for a period of time until it is dry enough to enter a furnace. The carbon enters the top of a multiple hearth furnace where it is heated at high temperatures to help drive off the molecules that have adsorbed on the surface of the carbon. Steam is used in a portion of the furnace to help cleanse the structure of the carbon. The final step in the regeneration process is a cold water quench tank which helps open the fissures or pore structure in the carbon to allow additional area for adsorption.

6.522 Specifics in Reactivation Process

1. Transfer of Spent Activated Carbon to Dewatering or Drain Bin. Spent activated carbon is carbon which has been effectively used so that it can no longer adsorb organic material. Spent carbon is conveyed under pressure to a dewatering bin by the use of a water slurry. Because the carbon tanks are under pressure, a pressurization of carbon in the form of a slurry can take place which pushes the carbon through the bottom of the pressure vessel and out into a piping system. The piping system will carry the carbon water slurry to a large bin for the dewatering process.

   The dewatering bin (also called a decanting bin) is a large open container which usually holds two cubic yards (1.5 cu m) of carbon (Figure 6.64). At the bottom of the dewatering bin is a screen port which allows water to flow from the carbon slurry. In this manner, the carbon can dry to some extent by sitting in the bin for a period of time and allowing the water to flow to the bottom of the bin and out for further treatment.

2. Adjusting Rate of Feed into Regeneration Furnace. The carbon regeneration furnace is usually a small multiple-hearth furnace (Figures 6.65 and 6.66). The furnace is designed to handle an optimum rate of activated carbon within the furnace for proper detention time for the regeneration of the carbon. The feed rate allows the proper number of pounds per hour to enter the furnace in the top hearth. The operator must be careful to adjust the feed rate according to the apparent density tests (procedures for performing apparent density tests are in the Appendix at the end of this chapter). If the apparent density is too high, the feed rate is too high and the carbon is not having a long enough detention time within the furnace to be regenerated properly. If the apparent density is too low and white ash is apparent on the edges of the carbon as it comes out of the furnace, the operator should speed up the feed rate because the carbon is being burned within the furnace.

3. Setting Automatic Controls for Temperature in Furnace. Most of the multiple hearth furnaces used for carbon regeneration have automatic controls to control the temperature within the furnace. The automatic controls adjust the air and gas ratio so that proper temperatures can be obtained at each successive level in the furnace. Each of the levels is considered a hearth and the normal regeneration furnace will have six hearths.

   The top hearth of a furnace is considered the drying hearth. The second hearth through the fifth hearth are considered the regeneration hearths. Usually, hearths numbered 3, 4 and 5 have the highest temperatures. Steam is usually added to hearths number 3 and number 4 to help cleanse the carbon of the organic material.

   In order to prevent air pollution, afterburners and/or scrubbers are usually found on the stacks to collect the gases which are emitted from a multiple-hearth carbon regeneration furnace. The scrubbers will pull out the organic material which comes off in the vapor. This scrubbed organic material is then returned to the treatment plant for further processing and additional treatment. In this manner, air pollution can be prevented.

4. Setting Controls for Steam to Portions of Regeneration Furnace. As indicated above, the normal hearth where steam is added for additional cleansing of the activated carbon of organic material are hearths number 3 and number 4. The operator should check the operations manual for the furnace to determine the desired steam valve settings for optimum steam levels. The valves should be set so that the proper amount of steam is injected relative to the feed rate into the furnace and the temperatures at the hearth setting.

5. Preventing Buildup of Carbon in Quench Tank. A cold water quench tank is usually found at the bottom of a multiple hearth carbon regneration furnace. Carbon is usually pumped from the quench tank to other tanks for purposes of *DEFINING.*[20] The operator should check the quench tank each hour to determine if the pumps are keeping up with the amount of carbon being produced from the bottom of the multiple hearth furnace. If carbon is allowed to build up in the quench tank, an overflow condition may occur and serious damage could result to the furnace if the carbon is backed up into the bottom hearth.

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[20] *Defining. A process that arranges the activated carbon particles according to size. This process is also used to remove small particles from granular contactors to prevent excessive head loss.*

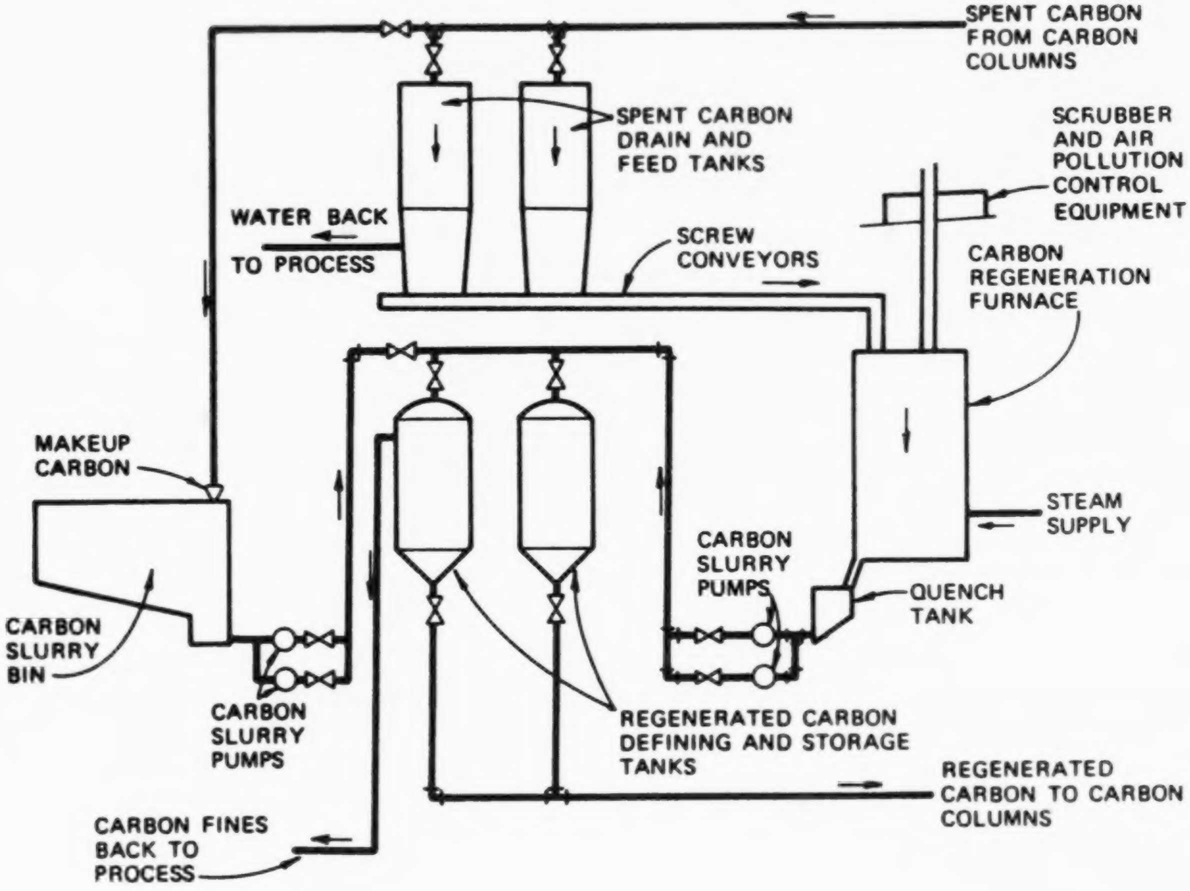

SPENT CARBON FROM CARBON COLUMNS
SPENT CARBON DRAIN AND FEED TANKS
SCRUBBER AND AIR POLLUTION CONTROL EQUIPMENT
WATER BACK TO PROCESS
SCREW CONVEYORS
CARBON REGENERATION FURNACE
MAKEUP CARBON
STEAM SUPPLY
CARBON SLURRY PUMPS
QUENCH TANK
CARBON SLURRY BIN
CARBON SLURRY PUMPS
REGENERATED CARBON DEFINING AND STORAGE TANKS
REGENERATED CARBON TO CARBON COLUMNS
CARBON FINES BACK TO PROCESS

Fig. 6.63 Carbon regeneration system schematic

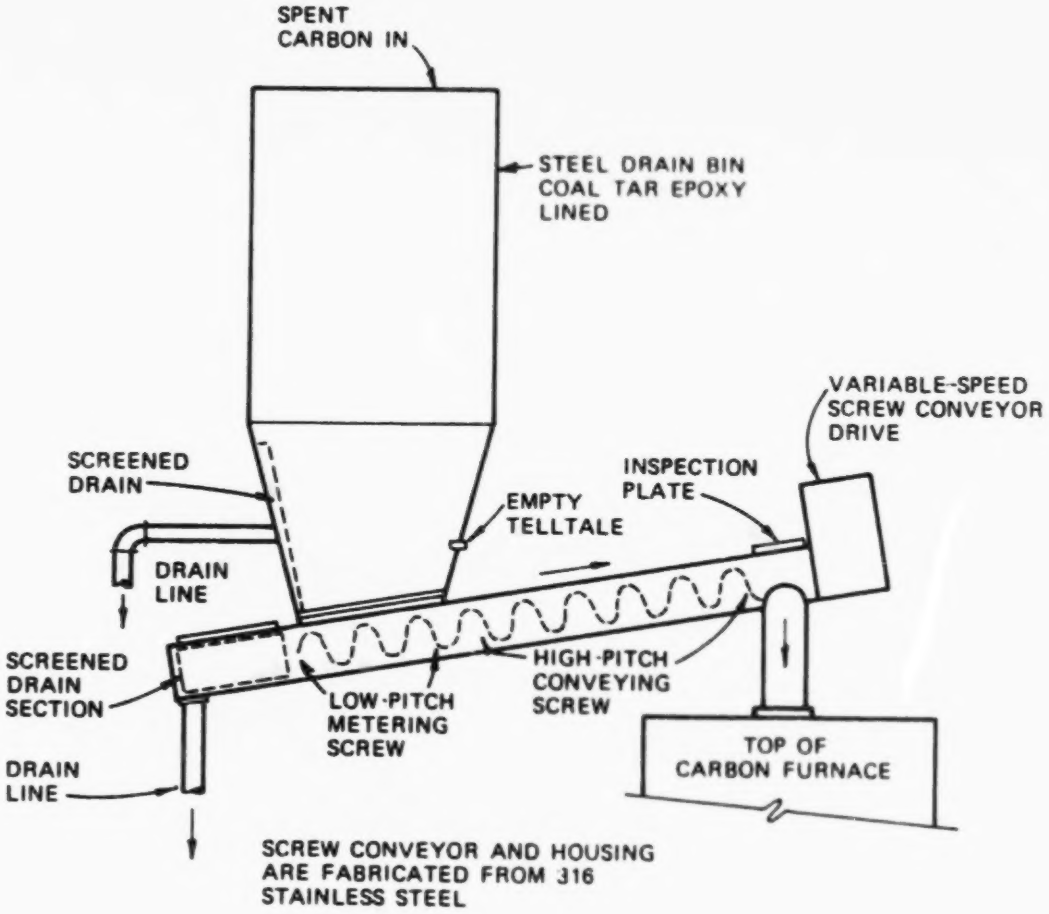

SPENT CARBON IN
STEEL DRAIN BIN COAL TAR EPOXY LINED
VARIABLE-SPEED SCREW CONVEYOR DRIVE
SCREENED DRAIN
INSPECTION PLATE
EMPTY TELLTALE
DRAIN LINE
SCREENED DRAIN SECTION
HIGH-PITCH CONVEYING SCREW
LOW-PITCH METERING SCREW
TOP OF CARBON FURNACE
DRAIN LINE
SCREW CONVEYOR AND HOUSING ARE FABRICATED FROM 316 STAINLESS STEEL

Fig. 6.64 Spent carbon drain bin and furnace feed arrangement

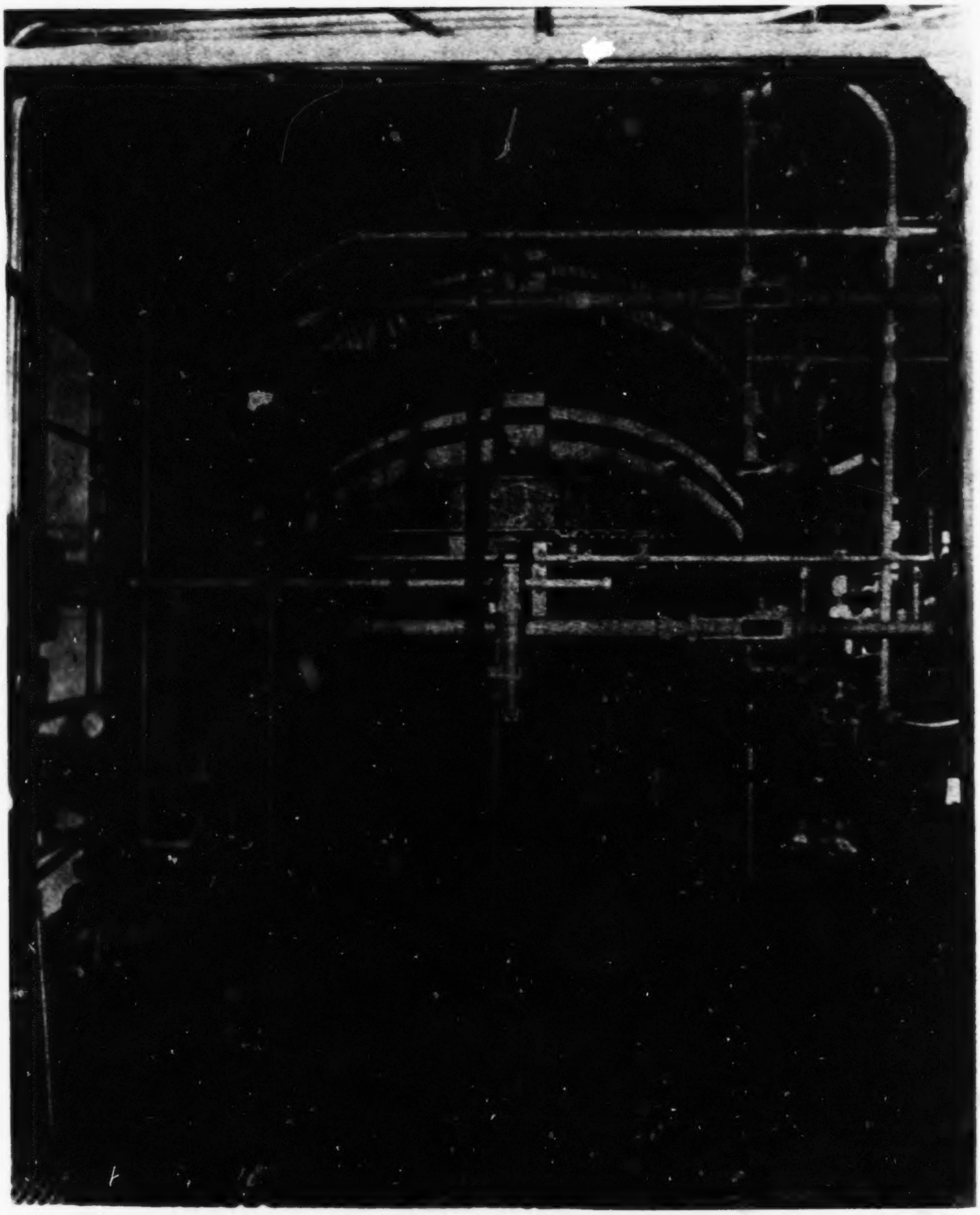


Fig. 6.65 Carbon regeneration furnace

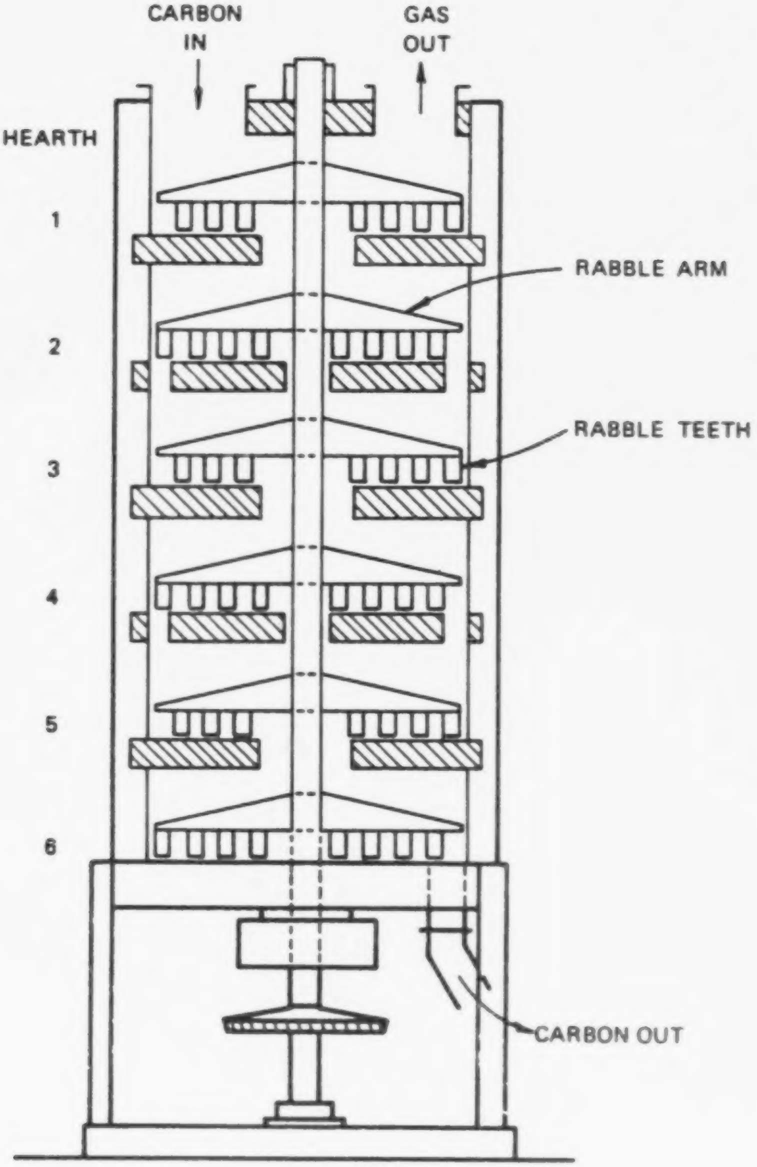

CARBON IN
GAS OUT
HEARTH
1
2
3
4
5
6
RABBLE ARM
RABBLE TEETH
CARBON OUT

Fig. 6.66 Cross-sectional view of multiple-hearth furnace

6. Pumping Reactivated and Quenched Carbon to Defining Tanks. Because of the corrosive nature and the granular form of activated carbon, centrifugal pumps and other vaned pumps will not be adequate for pumping an activated carbon slurry. The most common pump used for pumping a carbon slurry is a diaphragm pump. The operator should check to be certain that the diaphragm pumps are pumping the quantity of carbon necessary in order to keep up with the regeneration process.

7. Defining the Regenerated Carbon. Because of the movement of the carbon through the regeneration furnace and because of the quenching operation, small particles of granular activated carbon may break off into the carbon slurry as it is pumped from the quench tank. The fine particles of regenerated carbon must be defined in order to prevent clogging of screens in the carbon column reactors and to prevent suspended solids from being discharged in the effluent from the treatment plant.

   A defining tank or wash tank (Figure 6.67) for the regenerated carbon consists of a pressure vessel with screens. Water flows through and around the carbon, floating the smaller, lighter pieces of carbon fines back into treatment processes where the carbon fines can be further removed.

   The operator should use the defining tanks to be certain that the carbon has been washed as thoroughly as possible to prevent the small particles of carbon from causing further problems within the adsorption process. An adequate amount of time must be given to the defining process to be certain that as many of the fine particles are removed as possible.

8. Pumping Carbon to the Top of Carbon Column Reactors. After the regeneration process, activated carbon in a slurry form can be either pumped or pushed under pressure through a piping system to the tops of the carbon column reactors. Because the defining tanks are usually pressurized, it is normal to use the pressure from those vessels to force the carbon slurry back to the carbon reactors through the piping system.

   The operator must make sure that the slurry contains enough water to prevent any clogging within the piping or valving system as the carbon is returned to the carbon column reactors.

9. Troubleshooting of Regeneration Process. One of the common problems that occurs in the activated carbon regeneration process is the plugging of piping as the carbon is pushed from one place to another in a slurry. Black iron pipe is commonly used to transport carbon slurry. The black iron does not degrade as readily as other steel pipe due to the corrosiveness of the activated carbon. The black iron is put together with flanged joints so that the joints can be removed and elbows taken off to clean a plugged line if necssary.

   Other troubleshooting areas that must be watched closely by the operator include a) the feed rate to the regeneration furnace, b) the buildup of carbon in the quench tank, c) the pumping capacities of the carbon slurry d) the temperature levels in the carbon regeneration furnace and e) excessive burning of the activated carbon in the regeneration process.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 452.

6.5H What is regeneration of activated carbon?

6.5I What happens if the feed rate is too high to the carbon regeneration furnace?

6.5J What happens if the feed rate is too low to the carbon regeneration furnace?

6.5K How is the temperature controlled in a carbon regeneration furnace?

6.5L What is the purpose of the defining tank for the regenerated carbon?

6.53 Sampling and Analysis

6.530 Sampling

Sampling is very important in the operation of the activated carbon process. The operator should sample both influent and effluent to help determine removal efficiencies of organics and to determine the quantities of carbon fines remaining in the effluent from the process.

6.531 Analysis

Determination of removal efficiencies of organics is accomplished by running chemical oxygen demand tests and turbidity measurements. Other tests are run to help determine the status of the carbon in the carbon column contactors. Samples should be taken at least once a day on each carbon column to include both influent and effluent. The types of lab analyses that must be performed in order to achieve the highest efficiency of operation with the activated carbon regeneration process include apparent density of regenerated carbon, total ash of regenerated carbon, iodine number, molasses number, hardness number, abrasion number and sieve analysis. Details on how to perform these tests are contained in the Appendix at the end of this chapter.

APPARENT DENSITY OF REGENERATED CARBON • TOTAL ASH OF
REGENERATED CARBON • IODINE NUMBER • MOLASSES
NUMBER • HARDNESS NUMBER • ABRASION
NUMBER - - - SIEVE ANALYSIS

6.54 Operational Strategy

6.540 Daily Operating Procedures

Once each shift, the operator in charge of the carbon adsorption process should check to be certain that:

1. The rate of flow is set properly for each carbon adsorption tank;
2. Head losses measured through each carbon adsorption unit are within normal operating ranges;
3. Backflushing of carbon columns takes place when head losses build up or at least once per day;

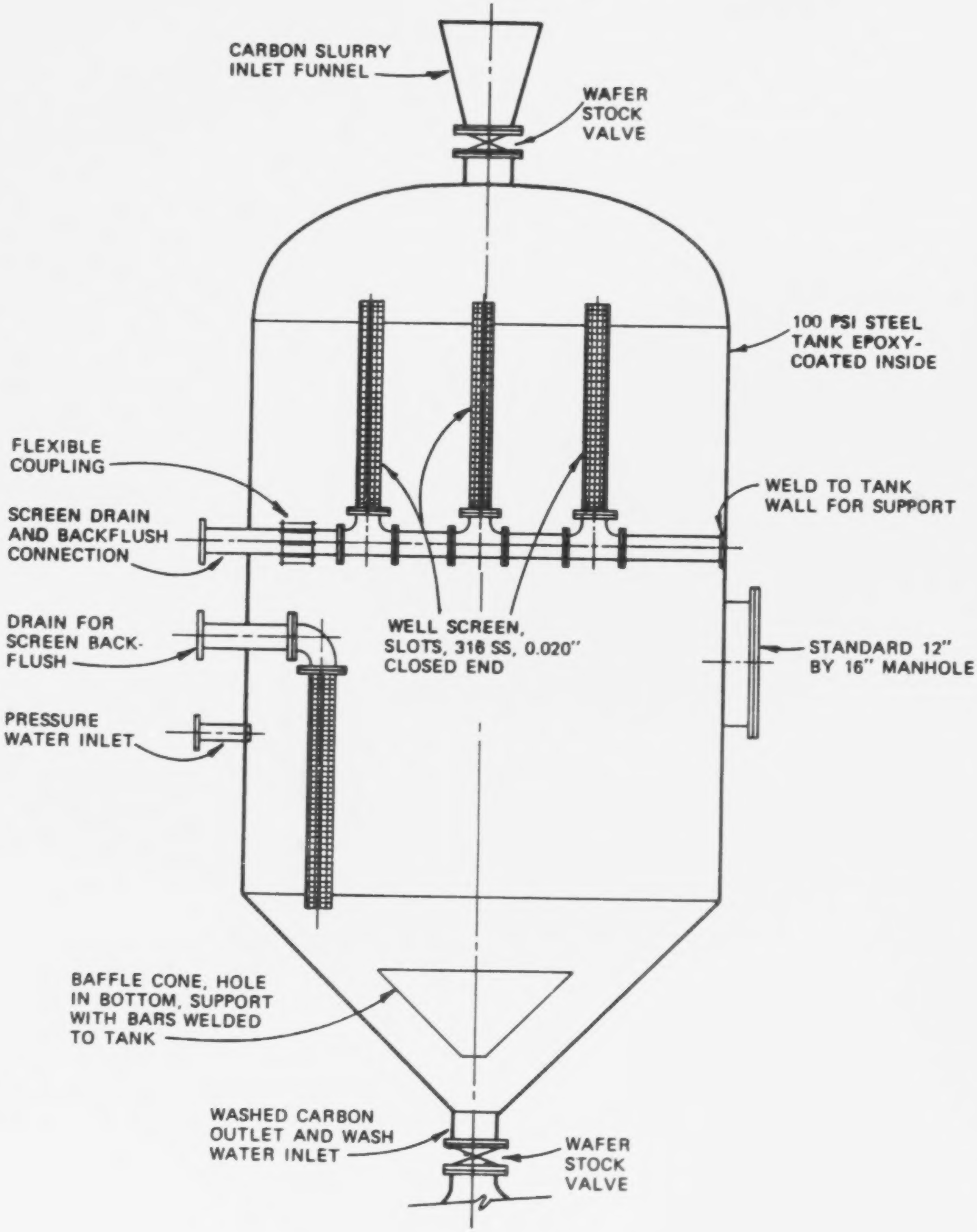

CARBON SLURRY INLET FUNNEL
WAFER STOCK VALVE
100 PSI STEEL TANK EPOXY-COATED INSIDE
FLEXIBLE COUPLING
SCREEN DRAIN AND BACKFLUSH CONNECTION
WELD TO TANK WALL FOR SUPPORT
DRAIN FOR SCREEN BACK-FLUSH
WELL SCREEN, SLOTS, 316 SS, 0.020" CLOSED END
STANDARD 12" BY 16" MANHOLE
PRESSURE WATER INLET
BAFFLE CONE, HOLE IN BOTTOM, SUPPORT WITH BARS WELDED TO TANK
WASHED CARBON OUTLET AND WASH WATER INLET
WAFER STOCK VALVE

Fig. 6.67 Regenerated carbon wash tank
(For 8×30 mesh carbon)

4. Daily samples are taken from each carbon reactor for both influent and effluent;
5. All valving is correctly set for normal operation;
6. If carbon is being regenerated, the furnace and feed rates are proper for a complete regeneration of the granular activated carbon; and
7. A daily log is kept of any problems that occur such as plugged screens, excessive head losses, problems with the regeneration furnace, plugged lines or any other abnormal conditions.

6.541 Abnormal and Emergency Conditions

1. Low COD Removal Efficiencies. If low chemical oxygen demand removal efficiencies are recorded for the activated carbon process, the operator must prepare for regeneration. The common reason for low removal efficiencies of organic matter is plugging of the fissures within the granular activated carbon so that adsorption efficiencies are impaired.

   By sampling and analyzing COD removal efficiencies for each carbon contact reactor, you will know when the regeneration process should begin. As soon as low removal efficiencies of organic matter are reported by the laboratory, begin preparation for the regeneration cycle. Take carbon columns off line, remove carbon from the bottom and prepare for regeneration in the multiple hearth carbon furnace. Prepare the furnace, bringing it up to the proper temperature and adjusting both carbon feed rate and the steam quantities for the regeneration process.

   During the process of adsorption, there are certain losses in the carbon mass. These losses will lower the quantities of available activated carbon in the adsorption process. To counteract the low quantities, be prepared to add fresh make-up carbon to any carbon column whose total quantity of granular activated carbon is low. COD removal efficiencies should improve after fresh carbon is added to the system.

2. High Head Losses. During the operation of the activated carbon adsorption processes, the head loss will increase. However, should head losses continue to remain high even after backflushing, be prepared to inspect the carbon columns.

   Inspection of the carbon columns is necessary to determine if a screen is completely plugged or collapsed. High head losses may also indicate that the amount of carbon in the adsorption reactor is too high and therefore causes plugging of the screens.

3. Fouling of Activated Carbon Granules with Suspended Solids. The carbon adsorption process usually follows other wastewater treatment units. Occasionally, the other treatment units may fail and organic matter and suspended matter in large concentrations may enter the carbon reactors. This can cause a fouling of the activated carbon granules and therefore impair the adsorption capabilities.

   When you suspect a fouling of the carbon granules with suspended solids, immediately backflush the carbon contactor in attempts to dislodge and flush out as much of the suspended solids as possible. Because most of the suspended solids will be trapped at the lower portion of the carbon reactor due to the upflow operation, an extra regeneration cycle may be required in order to burn off the excess suspended solids.

4. Plugged Screens. Because of the upflow configuration for normal operation of an activated carbon column, the bottom screens on the tank will seldom plug with debris and suspended solids. The screens that do tend to plug with carbon fines and suspended solids are the top screens located at the highest point or effluent end of the carbon reactor.

   When screens are plugged, the head losses will increase substantially through the carbon reactor. Backflush the screens in order to dislodge the plugged portions. Occasionally, backflushing will not be adequate to dislodge material trapped in the screens. When this happens, enter the carbon column and wire brush the screens in order to alleviate the plugging problem.

5. Collapsed Screens. Do not attempt to force more flow through the carbon column reactor than the design specifications allow. Extreme pressures can build up within the carbon column and cause severe damage to the carbon tank or to the screens within the vessel.

   The screens located within the vessel may collapse if excess pressure from within builds up due to negligence on the part of the operator. The high pressure from within forces against the zero or negative pressure on the other side of the screens or effluent side. This pressure can cause the screen to collapse and it will have to be replaced.

6. Air Pockets. Air pockets can develop when the carbon column reactor is filled too fast. Whenever the carbon column is empty, fill it slowly to allow air to escape through the automatic air escape valves at the top of the vessel. By filling the tank slowly, air is pushed ahead of the water as it enters the bottom of the tank and will escape without forming air pockets within the body of the granular carbon. Air pockets must be eliminated from the carbon column reactors to prevent short-circuiting. If air pockets develop inspite of slow filling rates, backflushing will sometimes eliminate them.

7. Degradation of Tank and Piping Interior Coatings. Because of the corrosive nature of activated carbon in its granular form, interior pipe and tank coating is supplied prior to the placement of the carbon columns into service. At least once every six months, the operator should check the inside of the activated carbon tank to be certain that the coating has not scaled or chipped away from the interior metal surface. If you find a chipped spot, contact the supervisor and have the spot repaired using a coal tar epoxy to seal the interior lining.

8. Failure of Upstream Processes. Because the carbon adsorption process is usually the last process in the wastewater treatment plant, the efficiency is highly dependent on the proper operation of any processes that precede the carbon

units. When upstream processes fail, a serious reduction in efficiency of the carbon process may result. If the treatment plant is equipped with an emergency holding pond, it may be in the best interest of the operation of the treatment plant to temporarily store inadequately treated wastewater rather than pumping it through the activated carbon columns. The better the quality of water which enters the carbon column reactors, the more efficient the adsorption process becomes. If wastewater is fouled with suspended solids and other matter, the adsorption process will be impaired and the operation will become more expensive due to unneeded regeneration of the activated carbon.

6.542 Sampling Ports

A small pipe can usually be found at the top of the carbon reactors from which you can sample effluent from the carbon columns. Likewise, the effluent from the process which precedes the carbon adsorption process can be sampled. In this way, the operator can obtain analyses of the influent and effluent of the adsorption process. This will be important in determining the efficiency of the organics removal through adsorption.

6.543 Abnormal Conditions Regarding the Carbon Regeneration Furnace

1. Refractory Brick in Interior of Furnace. Because of the high temperatures within a multiple hearth carbon regeneration furnace, certain elements may deteriorate. Check for deterioration of any of the refractory brick on the interior of the furnace. The brick should be in good shape in order to prevent the high heat from reaching the metal exterior of the furnace. If the high heat is not adsorped or insulated by good refractory brick, the furnace metal may warp and serious damage could result.
2. Air and Gas Mixture for Proper Temperature. Although most carbon regeneration furnaces automatically regulate the air and gas ratio for temperature control, you should inspect this ratio to make sure that it is correct. Should the air/gas mixture ratio become incompatible with proper temperature operation, adjust either the air or the gas in order to provide proper firing of the furance and adequate temperatures for the regeneration process.
3. Furnace Rabble Arms. The high-heat interior to the activated carbon regeneration furnace can seriously warp the rabble arms which move the carbon within the furnace. Be very careful that rabble arms are not stopped where burners can force direct heat upon the metal. When this occurs, the rabble arms tend to melt and sag causing serious damage to the furance.

   Also, check the teeth on the rabble arms to be certain that they have not worn out and can function properly. The teeth should be able to move the carbon within the furnace and the bottom of the teeth should be approximately one quarter inch (60 mm) off the refractory brick of each hearth. Rabble teeth should be replaced if they are worn. Worn rabble teeth allow carbon to pile up in one spot which could seriously damage the furnace structure.
4. Regenerated Carbon Slurry Pumps. Because activated carbon cannot be pumped through the standard centrifugal pumps, diaphragm pumps are commonly used for pumping carbon slurry. Periodically inspect the ball checks and diaphragms on the slurry pumps to be certain that no excessive wear is apparent. The capabilities of the pumps may be seriously impaired if carbon is allowed to interfere with the ball check or diaphragm. You can visually check the amount of slurry pumped by each slurry pump. When the quantity of slurry appears to be substantially reduced, proceed with maintenance steps for clearing any plugging problems or diaphragm malfunction.
5. Defining Tank Maintenance. The carbon column defining tank is similar to the activated carbon adsorption vessels. This is a pressure tank which has screens for defining the carbon after it has been regenerated or while the carbon is fresh and available as a make-up carbon.

   Be certain that any screens in the make-up carbon or regenerated carbon defining tank are clear and free from blockage. Also, make certain that any air scrubbing devices or carbon dust collector mechanisms are functioning properly. Be very careful not to breathe carbon dust as it can be harmful to your health.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 452.

6.5M List the possible causes of high head losses through an activated carbon process.

6.5N Why should the activated carbon column reactor be filled slowly?

6.5O What would you do if a wastewater treatment process upstream from a carbon adsorption process failed?

6.5P List the problems an operator could encounter when operating a carbon regeneration furnace.

6.55 Safety

6.550 Carbon Adsorbs Oxygen

One feature of the activated carbon adsorption process is that it adsorbs oxygen molecules from the atmosphere. Operators or maintenance personnel should be very careful when entering a carbon column tank or any enclosed room where carbon is in contact with the atmosphere. Prior to entering a carbon column reactor vessel, the operator or maintenance personnel should be wearing a self-contained breathing apparatus to provide oxygen and also a safety harness. The operators should be certain that two operators are standing by whenever a person enters a carbon column tank. This serves as a safety precaution so that if the person within the tank is overcome due to lack of oxygen, the other operators or maintenance personnel can pull the affected individual out of the carbon vessel.

6.551 Carbon Dust

Fresh or dry carbon tends to shed a certain amount of dust particles when moved or handled. Be very careful when handling dry activated carbon to avoid inhaling the dust. Wear a face mask to prevent the carbon dust from entering your lungs.

6.552 Excessive Pressures Within Carbon Contactor Tank

Make every effort to prevent excessive pressure buildup within the carbon contactor vessels. Excessive pressure may be caused by too high a flow entering the vessel or by collapsed or plugged screens. If pressures are too high within the carbon vessel, the vessel itself could explode or rupture.

6.56 Loading Guidelines

6.560 Typical Loading Rates

Two types of loading rates are used for activated carbon adsorption processes: 1) hydraulic loading rates, and 2) chemical oxygen demand or organic loading rates.

6.561 Hydraulic Loading Rates

The typical hydraulic loading rates entering a carbon adsorption column range from 2 to 10 gallons per minute per square foot (1.3 to 6.8 liters per second per square meter). The average hydraulic loading rate (or surface loading rate) is 5 gallons per minute per square foot (3.4 liters per second per square meter).

6.562 Chemical Oxygen Demand Loading Rates

Chemical oxygen demand loading rates average at one-half pounds of COD applied per day for each pound of carbon (0.5 kg COD/day/kg of carbon) in the contact vessel.

6.57 Review of Plans and Specifications

6.570 Loading Station for Truck or Train Delivery of Fresh Activated Carbon

Because it is important to add make-up or fresh activated carbon periodically, an unloading station is needed to receive the fresh carbon for the adsorption process. The unloading station should have a proper turnaround if it is a truck station. The station should be close enough to the rail center for easy unloading if it is delivered by rail.

Bagged carbon can sometimes be unloaded rapidly by machine if the proper suction equipment is available to pull carbon from the bags. Otherwise, operators must empty each bag into the fresh carbon handling station on an individual basis.

If bulk carbon is to be unloaded at the treatment plant, it is best to have a suction device to unload the carbon from the bulk container so that manpower can be cut to a minimum. By providing a suction device, dust and other hazards can be reduced or eliminated.

6.571 Valving Placed at Easy-to-Reach Locations

Check the design of the activated carbon adsorption process station to be sure that all valves indicated on the plans are easy to reach. The valves, if overhead, should be no higher than six feet (1.8 m). Valves that are at the top of carbon columns should be easy to reach from a catwalk or other handrailed-protected operation viewing facility.

6.572 Dust Control for Unloading Fresh Carbon

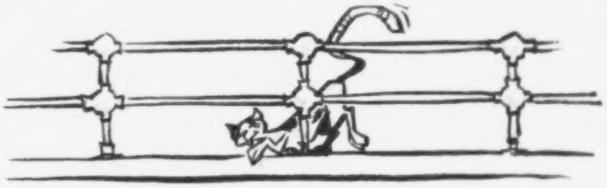
When unloading fresh carbon, be certain that exhaust fans are operating and that all staff are wearing face masks to prevent inhaling the carbon dust. The operator should check the plans to be certain that dust control is adequate to protect all personnel.

6.573 Proper Ventilation in Carbon Regeneration Furnace Room

Because of the heat and dust that can be emitted from a carbon regeneration furnace, check the plans to be certain that adequate ventilation is provided within the furnace room. Proper ventilation and air circulation is mandatory in order to protect the personnel from excessive heat and exposure to fine particles of carbon, smoke and other hazardous material.

6.574 Scaffolding and Catwalks

Check plans to be certain that all catwalks and scaffoldings are protected with handrails to comply not only with OSHA standards but to ensure safety, particularly when the catwalks are located at the top of the carbon column reactors. Entrance and exit from access ports into carbon column reactors should be protected so that the chances of the operator falling are at a minimum.



6.575 Warning Alarms and Signs

Check the plans to be certain that alarms are adequate to notify personnel of excessive temperatures or lack of oxygen within a building. Be certain that the plans call for signs and warning systems posted at various locations so that all personnel are aware of the dangers associated with working around activated carbon.

6.576 Upstream Processes

Filtration is usually an upstream process prior to carbon adsorption. A holding tank or reservoir is desirable upstream from the carbon adsorption process in order to provide temporary storage in case of failure of other systems. Check plans to be certain that such a reservoir is provided for temporary or emergency storage. Failure of upstream processes would mean excessive organic or suspended solids loading on the activated carbon process, thereby reducing its effectiveness.

6.58 Additional Reading on Activated Carbon Adsorption

1. *HANDBOOK OF PUBLIC WATER SYSTEMS,* Gordon L. Culp, Russell L. Culp, George "Mac" Wessner, Van Nostrum Reinholdt Company, Mail Order Department, P.O. Box 668, Florence, Kentucky 41042. Price $89.00.
2. *OPERATION AND MAINTENANCE MANUAL FOR WASTEWATER RECLAMATION FACILITY,* South Tahoe Public Utility District, So. Lake Tahoe, CA 1974.
3. *PROCESS DESIGN MANUAL FOR CARBON ADSORPTION,* U.S. Environmental Protection Agency, Center for Environmental Research Information (CERI), 26 West St. Clair Street, Cincinnati, Ohio 45268.

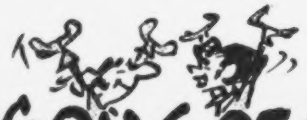
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 452.

6.5Q How could activated carbon cause an oxygen deficiency in a carbon column reactor vessel?

6.5R List the items you would consider when reviewing the plans and specifications for an activated carbon adsorption process.

6.5S What kinds of warning signs and alarms should be provided with an activated carbon adsorption process?



END OF LESSON 6 OF 6 LESSONS ON INDUSTRIAL WASTE TREATMENT

DISCUSSION AND REVIEW QUESTIONS

(Lesson 6 of 6 Lessons)

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 5.

35. How does activated carbon remove organic material from wastewater?
36. Why are pressurized upflow carbon contact chambers preferred over downflow pressure vessels?
37. Why must activated carbon be regenerated?
38. What tests should be run on the effluent of the activated carbon process and why?
39. What would you do if the results of lab tests showed low COD removal efficiencies from a carbon adsorption unit?
40. How can too high a pressure build up in carbon contactor vessels?

Please work the objective test next.

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

INDUSTRIAL OPERATING PROCEDURES

6.6 HOW TO OPERATE AN INDUSTRIAL WASTEWATER TREATMENT PLANT by Robert Wills, Jr.

The purpose of this section is to provide you with an outline of the procedures used to operate a wastewater reclamation and recycle facility at a specialty steel mill. The processes used are physical and chemical treatment processes, rather than the conventional biological treatment processes used to treat domestic wastes. By using this section as a guide, you should be able to develop similar procedures for the operation of industrial waste treatment facilities.

6.60 Routine Operational Control of a Specialty Steel Wastewater Reclamation and Recycle Facility

6.600 Description of Treatment Facilities

Wastewater treated at a steel mill facility comes from several different sources (Fig. 6.68). These sources include rolling mill wastewater, cooling tower waters, pickling rinse waters, boiler blowdown and mill furnace cooling tower waters.

Wastewaters are collected at six different pump stations located throughout the mill production facilities. The collected wastewater is pumped through three force mains to the wastewater reclamation and recycle facility.

The first treatment process is the aeration tank. *THE AERATION TANK IS NOT FOR BIOLOGICAL TREATMENT.* Wastes are blended in the aeration tank. Soluble iron is converted to insoluble iron that can be precipitated and settled out by the addition of ferric chloride ($Fe\ Cl_3$). During aeration some of the heat picked up by the water in the mill operation is liberated from the water.

Solids Control Tank A (SCTA or recycle water treatment tank A) is equipped with a turbine mixer to mix the chemicals (ferric chloride ($FeCl_3$) and polymer) with the water from the aeration tank. After mixing, the water enters the settling portion of the tank for clarification. Ninety percent of the effluent leaving tank A is returned to the steel mill for use as process water in the steel making operation. Necessary make-up water comes from the local municipal water supply. The remaining ten percent of the effluent from Tank A goes to effluent treatment tank B (SCTB or Solids Control Tank B).

In Tank B the pH is adjusted by the addition of lime or some other caustic to precipitate metals such as chromium and copper. This procedure for pH control also improves the settling of small floc and enhances effluent quality before discharge.

Solids precipitated and removed from tanks A and B are pumped to a gravity thickener where they are mixed together and resettled. Since the sludge from the thickener consists mainly of inorganic materials (metal flocs, rust, dirt) and flocculating agents, the sludge compacts to a high solids content and is very dense. Domestic wastewater sludges are high in organic material and will not compact to a high degree.

Thickened sludge is dewatered by a vacuum filter. A very dry cake is produced that is disposed of in a landfill.

Treated wastewater is pumped from the recycle wet well back to the mill based on the mill's demand for water.

The remainder of this section is in outline form to show you the procedures that must be developed to successfully operate industrial wastewater reclamation and recycle facilities.

6.601 Operational Strategy

A. Quality effluents (recycle and discharge) can be achieved by careful monitoring of the influent waste stream and the operation of the chemical feed systems in the treatment facilities (Figures 6.69 and 6.70).

   1. Influent waste stream must be monitored due to the large variability in flows. The main water quality indicators that must be monitored are:

      a. Low pH. This indicates an acid dump which means you probably have high concentrations of soluble metal coming in. In addition, low pH may cause the following problems:

         1. Foaming due to cleaning additives in pickling solutions.
         2. Previously precipitated metals may resolublize due to the depressed pH causing higher metal concentrations in the "clarified" water than in the influent.
         3. Reduced treatment efficiencies due to the treatment chemical effectiveness at low pH levels.
         4. Increased corrosion rates in the collection, transmission, treatment, and recycle systems.

      b. High pH. This indicates an alkaline dump which may or may not affect the plant. High pH may cause the following problems:

         1. Foaming caused by alkaline cleaning solutions.
         2. Iron floc carryover. Large tannish-orange floc which is extremely difficult to settle may be present in the entire system. This may cause plugging of filter and strainers in the recycle lines, coating on heat exchanger surfaces, and violation of your NPDES permit due to visible solids carryover and high metal concentrations.
         3. Reduced treatment efficiency due to increased solubility of some metals at higher pH values.
         4. Reduced efficiencies for treatment chemicals used in process.
         5. Scale build up in recycle system, especially at heat transfer areas.

      c. High solids concentration.

         1. Indicates a large dump of pollutants which may overload treatment plant, dramatically reduce its efficiency and increase pollutant recycle/discharge.
         2. You must monitor and determine the plant's average influent solids concentration and then determine the maximum loading the plant can take under normal operating conditions.

SCHEMATIC OF EXISTING SYSTEM

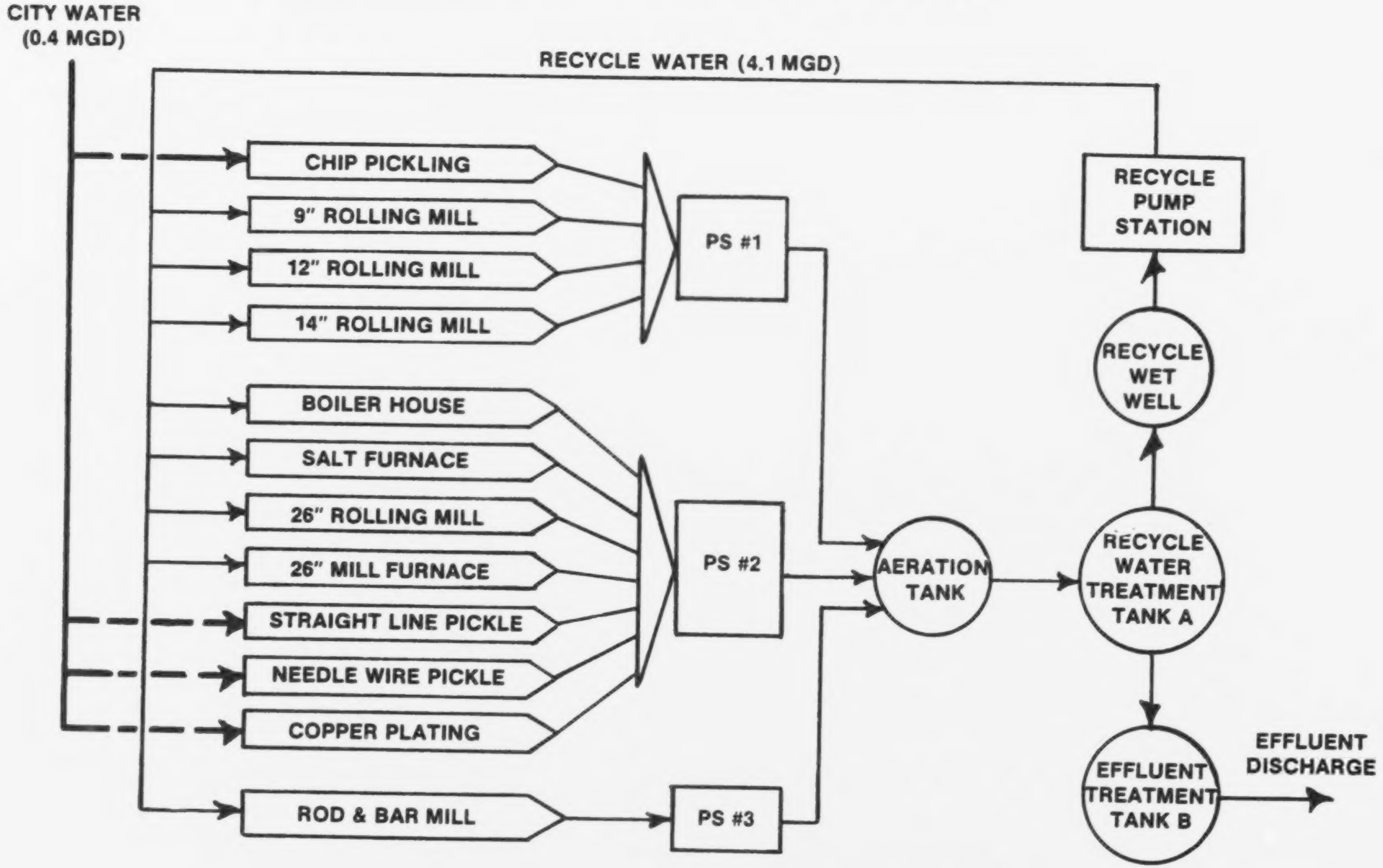
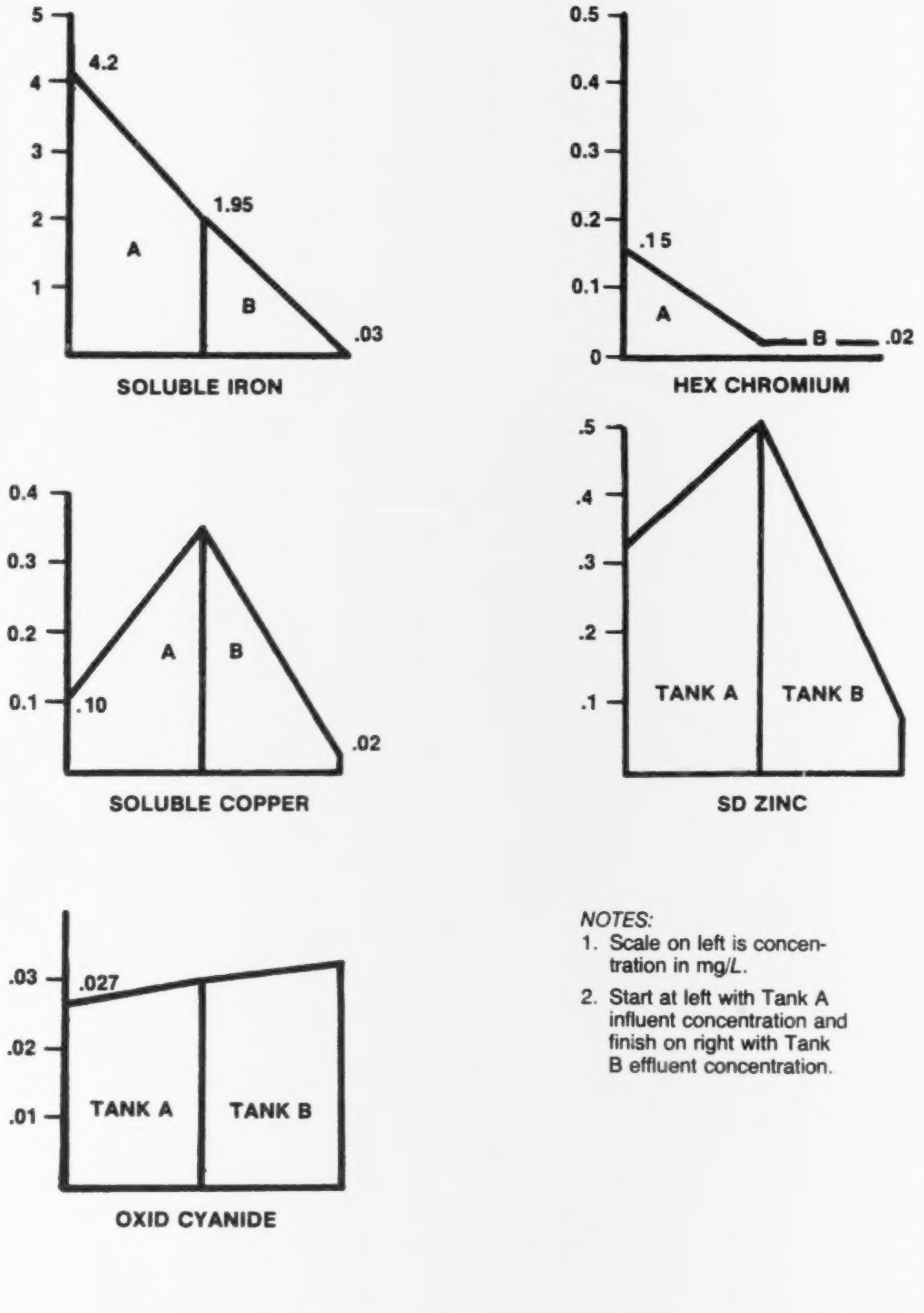

CITY WATER
(0.4 MGD)
RECYCLE WATER (4.1 MGD)
CHIP PICKLING
9" ROLLING MILL
12" ROLLING MILL
14" ROLLING MILL
BOILER HOUSE
SALT FURNACE
26" ROLLING MILL
26" MILL FURNACE
STRAIGHT LINE PICKLE
NEEDLE WIRE PICKLE
COPPER PLATING
ROD & BAR MILL
PS #1
PS #2
PS #3
AERATION TANK
RECYCLE WATER TREATMENT TANK A
RECYCLE WET WELL
RECYCLE PUMP STATION
EFFLUENT TREATMENT TANK B
EFFLUENT DISCHARGE

Fig. 6.68 Layout of steel mill wastewater sources and treatment facilities

CONCENTRATION REDUCTION DURING TREATMENT



NOTES:

1. Scale on left is concentration in mg/*L*.
2. Start at left with Tank A influent concentration and finish on right with Tank B effluent concentration.

Fig. 6.69 Effectiveness of waste removal during treatment

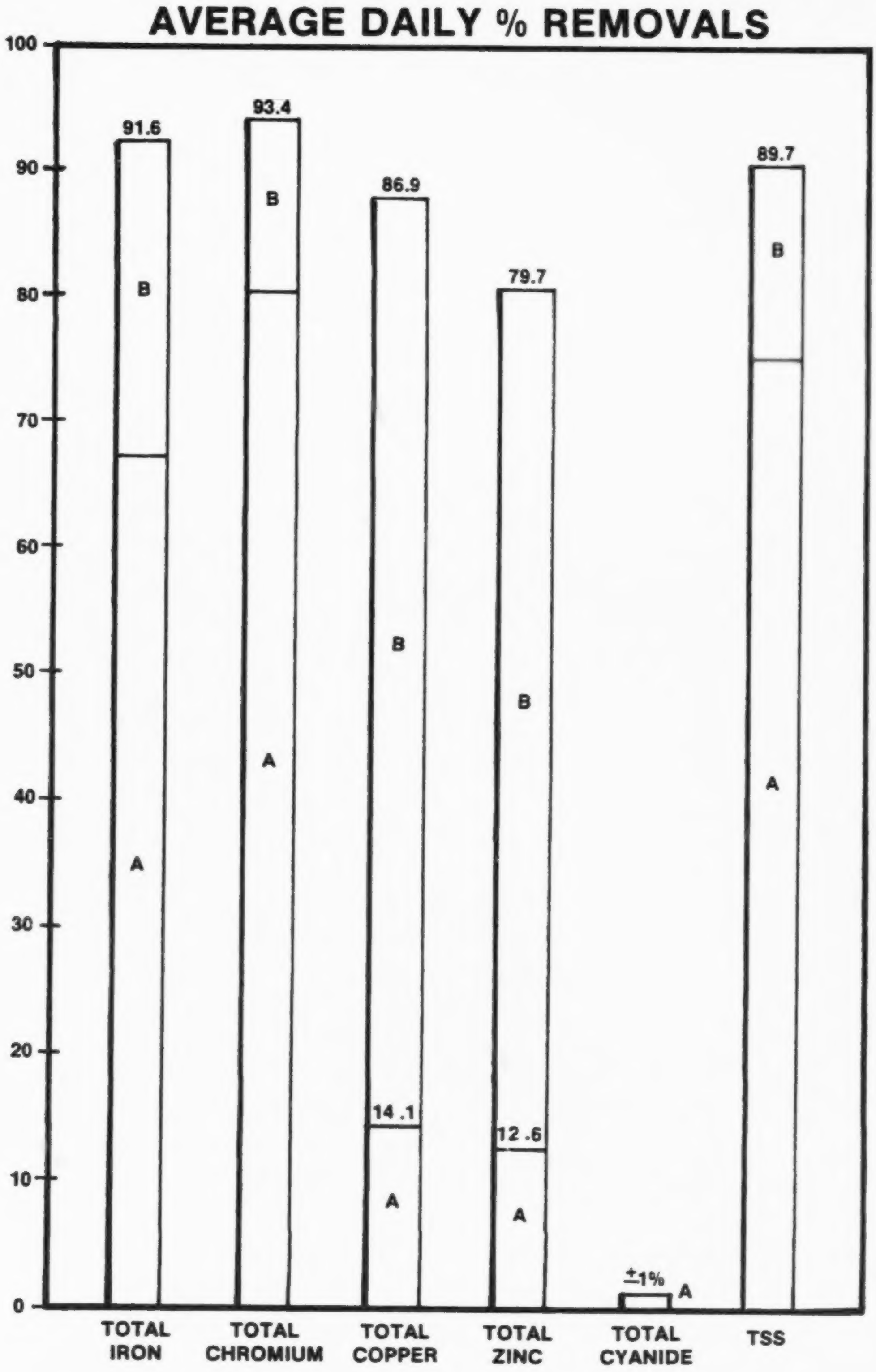


Fig. 6.70 Percent removals from Tanks A and B

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d. Flow variations.
   1. High flows can cause problems by hydraulically overloading clarifier portions of Tanks A and B, thus decreasing effective treatment chemical dosages (on non-automatic flow paced controlled feed systems), accentuating short-circuiting (or other clarifier problems), or thermal shock (induced by excessive city water additions) (Fig. 6.71).
   2. Low flows can cause treatment chemical overdose (on non-automatic flow paced controlled feed systems) which can affect color, turbidity and cause some chemicals to act as dispersants.

e. Other indicators that may cause plant operation problems include:
   1. Oil and grease can indicate large dumps which can:
      a. Exceed oil and grease discharge limitations, even on units with skimmers.
      b. Affect chemical treatment.
         1. Suspended floc.
         2. Cause sludge floc to float instead of settle.
      c. Cause new or increase biological growths.
      d. Affect sludge compaction and dewatering abilities.
      e. Cause potential fire and safety hazards.
      f. Be aesthetically displeasing.
   2. Color.
      a. White or yellow green — may indicate emulsifiable oil and its related problem or lime slurry.
      b. Purple — potassium permanganate.
      c. Green — caustic solution.
   3. Odor.
      a. Acrid — check for acid.
      b. Petroleum — check for oils or solvents.

2. To improve treatment and effluent quality:
   a. Level out flows.
   b. Level out pH.
   c. Reduce contaminant fluctuations.
   d. Optimize chemical usage.

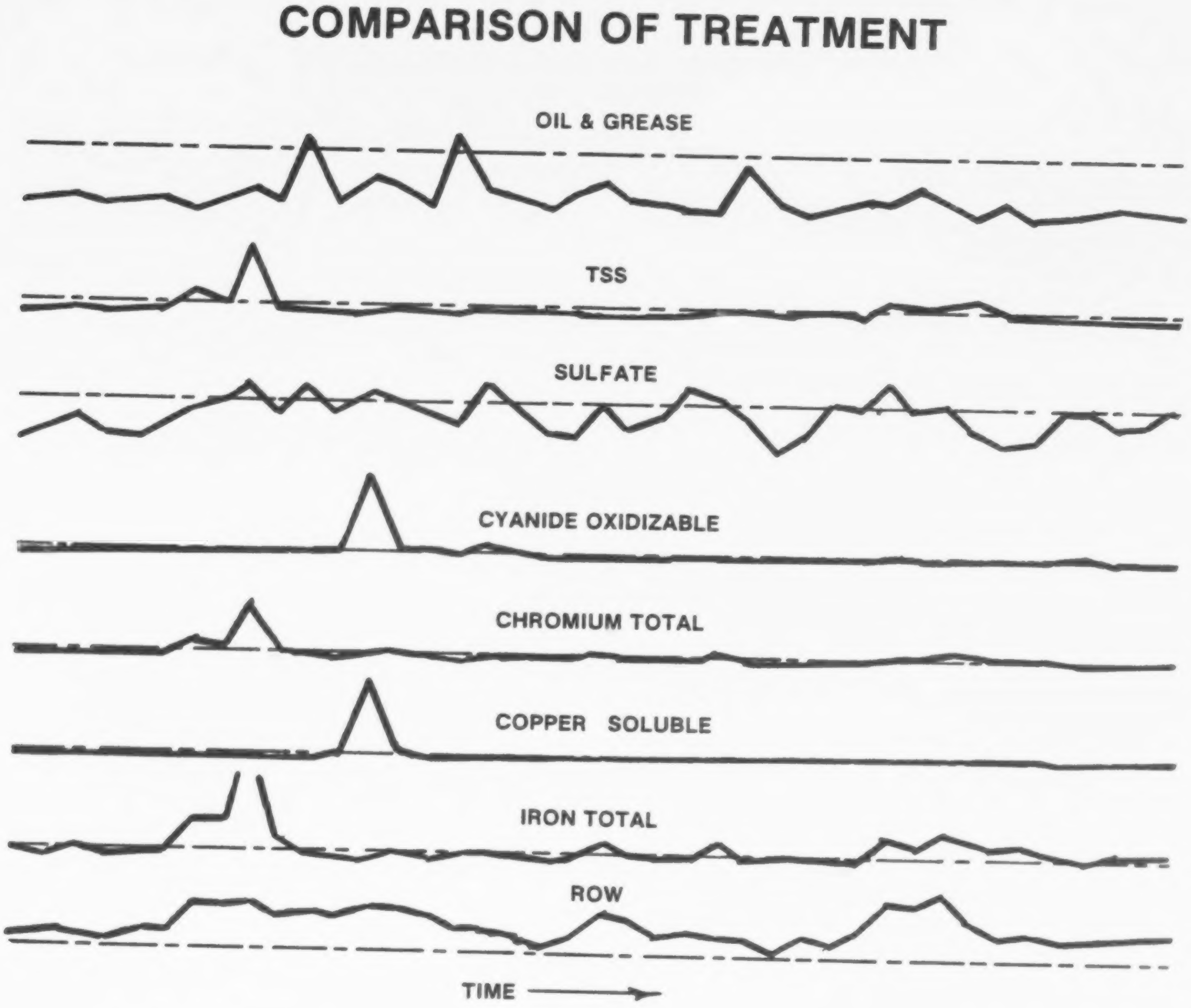
6.61 Daily Inspections

1. Review the wastewater treatment plant (W.W.T.P.) log book

2. Check all 24-hour chart recorders for unusual readouts or spikes.
   a. pH variations typically indicate problems at pickling lines or at ion exchange units being regenerated.
   b. Excessive effluent discharge typically indicates excess city water additions, check areas that have emergency cut in valves.
   c. Little or no effluent discharge.
      1. Not enough make-up water.
      2. Pump station is not returning recycled water to the W.W.T.P. This creates an unbalanced system because the pump station will flood and the W.W.T.P. will run out of recycled water.
      3. Recycled water is not being returned to the W.W.T.P.
   d. Recycled water pressure too high.
      1. Pressure relief valve inoperative.
      2. Recycle pump malfunction.
      3. Instruments controlling recycle pumps malfunctioning.
   e. Recycled water pressure too low.
      1. Pressure relief valve malfunction (stuck open).
      2. Instruments controlling recycle pumps malfunctioning.
      3. Recycle pump malfunction.
   f. Recycled water flow too high.
      1. If discharge pressure is low and wet well is falling, there is a break or leak in a recycled water line.
      2. If discharge pressure is high, pressure relief valve and/or instruments controlling the recycle pumps are malfunctioning.
   g. Wet well level too low or dropping.
      1. Valve controller on effluent discharge malfunctioning.
      2. Pump station is not returning recycle water to W.W.T.P.
      3. Recycle water not returning to W.W.T.P. due to water line break or leak.
      4. Needs more make-up water.

3. Review security log book for operational or maintenance problems.

4. Check effluent discharge quality and recycled water quality.
   a. If water is clear, free of suspended solids, floating solids, foam and oil and grease, go to item 5.
   b. If water contains:
      1. Suspended or floating solids or pinpoint floc:
         a. Check pH of influent and effluent.
            1. Too low or too high pH can redissolve some metals.
            2. Rapid pH change can upset treatment.
         b. Check chemical feed pumps.
         c. Check for excessive flow rate which could hydraulically overload the clarifier.



NOTES:

1. The spike of TSS aligns with a spike of Chromium Total and Iron Total.
2. The spikes of Cyanide Oxidizable and Copper Soluble indicate a problem at a copper coating line.

Fig. 6.71 Effluent quality as compared with target valves

   - d. Check operation of rake and turbine drive units.
   - e. Check mill operations for recent dump of oil or other material which may act as a dispersant.
   - f. Check for sudden changes of water temperature.

  2. Foam.
     - a. Check for dump of pickling (acid or alkaline) solution containing detergents.
     - b. Check for detergents from cleaning operations.
  3. Oil and Grease.
     - a. Check for large dump of oil and grease from mill operation.
     - b. Check oil skimmer operation.
     - c. Check effluent pH (pH fluctuations can break oil free from the water).

5. Walk around the entire plant, including recycle pump station, aeration tank and sludge thickener. Report any abnormalities.

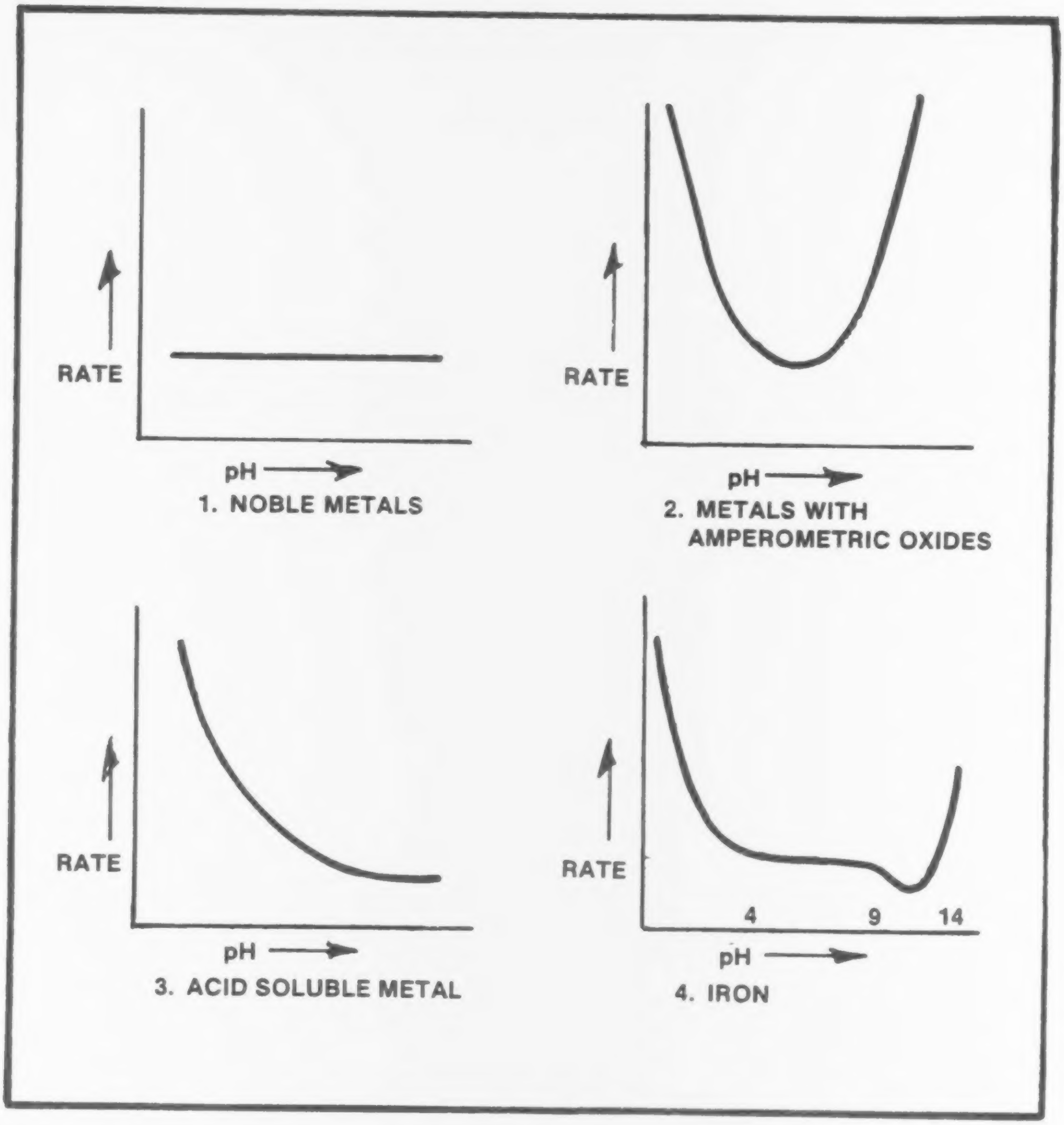
6.62 Process Adjustment

1. pH is the most important water quality indicator to control since it can dramatically effect coagulation, effectiveness of treatment chemicals, solubility of metals in the wastewater and the sludge, and corrosion/scaling tendency of the recycled water.
   - a. pH at the aeration tank should be controlled to meet the most effective pH range for the treatment chemicals (6.5 – 7.5).
   - b. pH of the recycled water should minimize scaling/corrosion in the plant. This value should be determined by considering other factors of the system. For example, hardness, alkalinity, free mineral acidity, TDS and to what types of processes the water is being applied.
   - c. pH of the effluent discharge must be within the NPDES permit limitations while at the same time maximizing metal removals.
     1. You may not be able to run at a pH value to minimize a specific metal solubility due to permit limitations.
     2. Adjust pH to the minimum solubility of the metal most restricted on your permit. See Figures 6.72, 6.73 and 6.74.
2. Frequent jar tests are required at each stage of treatment to insure the best results for chemical additions to the wastewater.
   - a. Be sure to get a representative sample of the wastewater for jar test and retest before altering feed rates.
   - b. File results of jar tests for future reference.
3. Know the mill production processes and potential problem areas.
   - a. If the W.W.T.P. is subject to large shock loads, try to reduce shock loads before they get to the W.W.T.P.
     1. The variability is a measure of a system's ability to handle fluctuations.
     2. Variability ratio = $\frac{\text{highest value}}{\text{lowest value}}$
     3. Typical variability ratios for specialty steel mill are shown in Figures 6.75 and 6.76.
     4. By reducing the variability ratio, the waste can be treated more efficiently thus achieving better contaminant reductions.
4. Minimize flow variations (Fig. 6.77)
   - a. Dampening or leveling out flow variations to and through the W.W.T.P. results in optimization of chemical usage and increased levels of treatment efficiency.
   - b. Methods for minimizing flow variations include:
     1. Limit pump station cycling by matching pumping rates to inflow to pump the same amount of water over a longer period of time instead of pumping high volume quickly, shutting down pumps and waiting for wet well to fill up.
     2. Determine the minimum pressure of recycled water that can adequately service the mill and adjust controls so that extra recycle pump won't come on until that pressure is not met.
     3. Set automatic valve operators to operate valve at the slowest possible speeds.
     4. Try to get mill start-ups staggered or manually start additional recycle pump and slowly open discharge valve as the demand increases.
   - c. Mill processes in which to expect excess city water additions:
     1. Processes which have emergency cut in valves to protect the process if the recycled water system goes down.
     2. Processes which have city water addition points or city water for backup.
     3. On days of poor recycle water quality or high recycled water and/or ambient temperature, check processes which have complained about similar problems in the past.

6.63 Day-to-Day Mechanical Operation

6.630 Clarifiers

- a. Rake drive speed should be adjusted to maintain:
  1. Proper sludge level.
  2. Proper sludge density.
  3. Proper torque reading.
  4. Proper solids recirculation to the reaction well.
  5. Proper oil skimming (if there are skimming devices on the rake arms).
- b. Turbine mixer drive speed should be adjusted to maintain:
  1. Proper mixing of influent and chemicals.
  2. Proper mixing with previously formed floc.



1. NOBLE METALS

2. METALS WITH AMPEROMETRIC OXIDES

3. ACID SOLUBLE METAL

4. IRON

Fig. 6.72 Effects of pH on corrosion rates

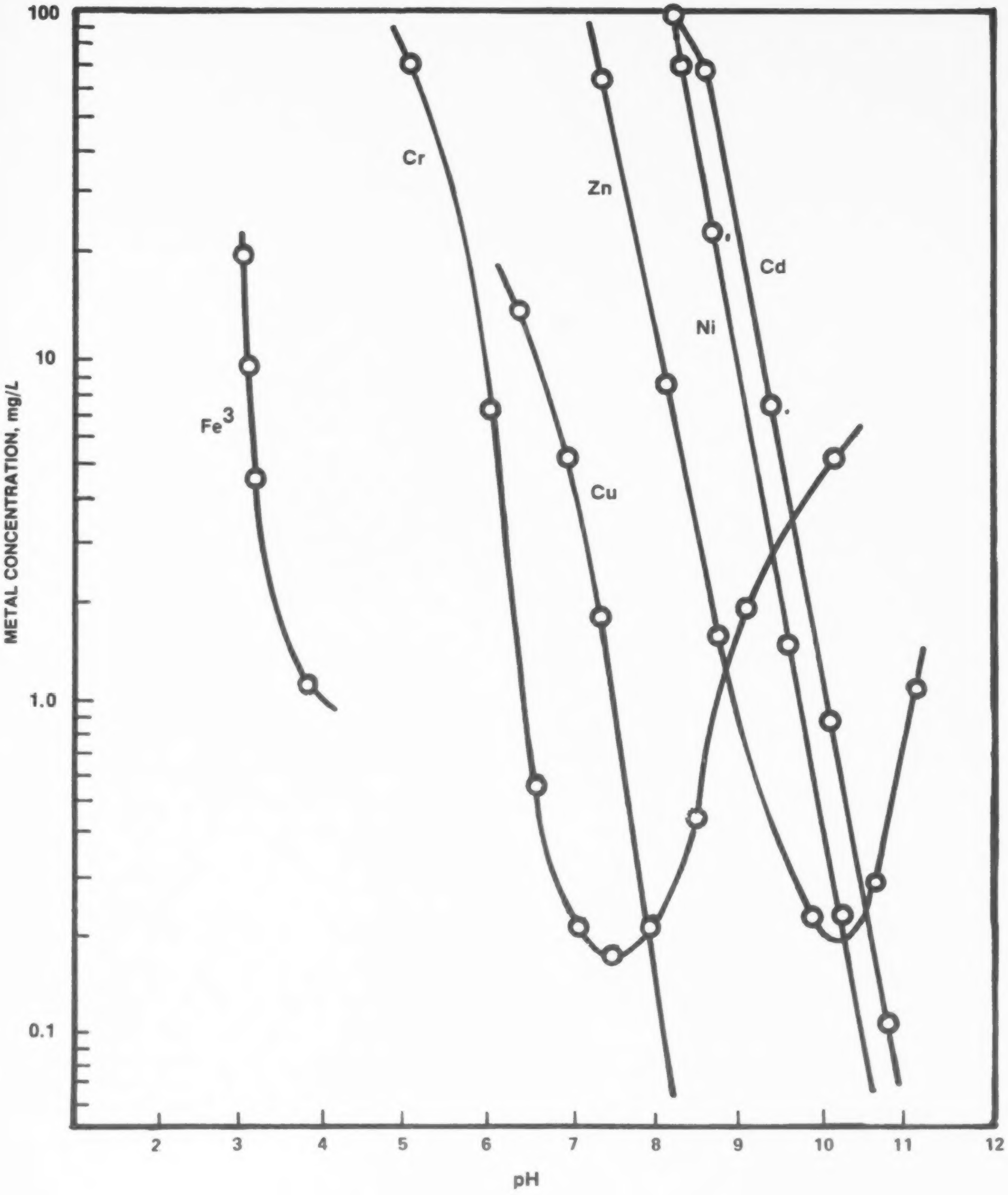


Fig. 6.73 Effects of pH on metal concentration

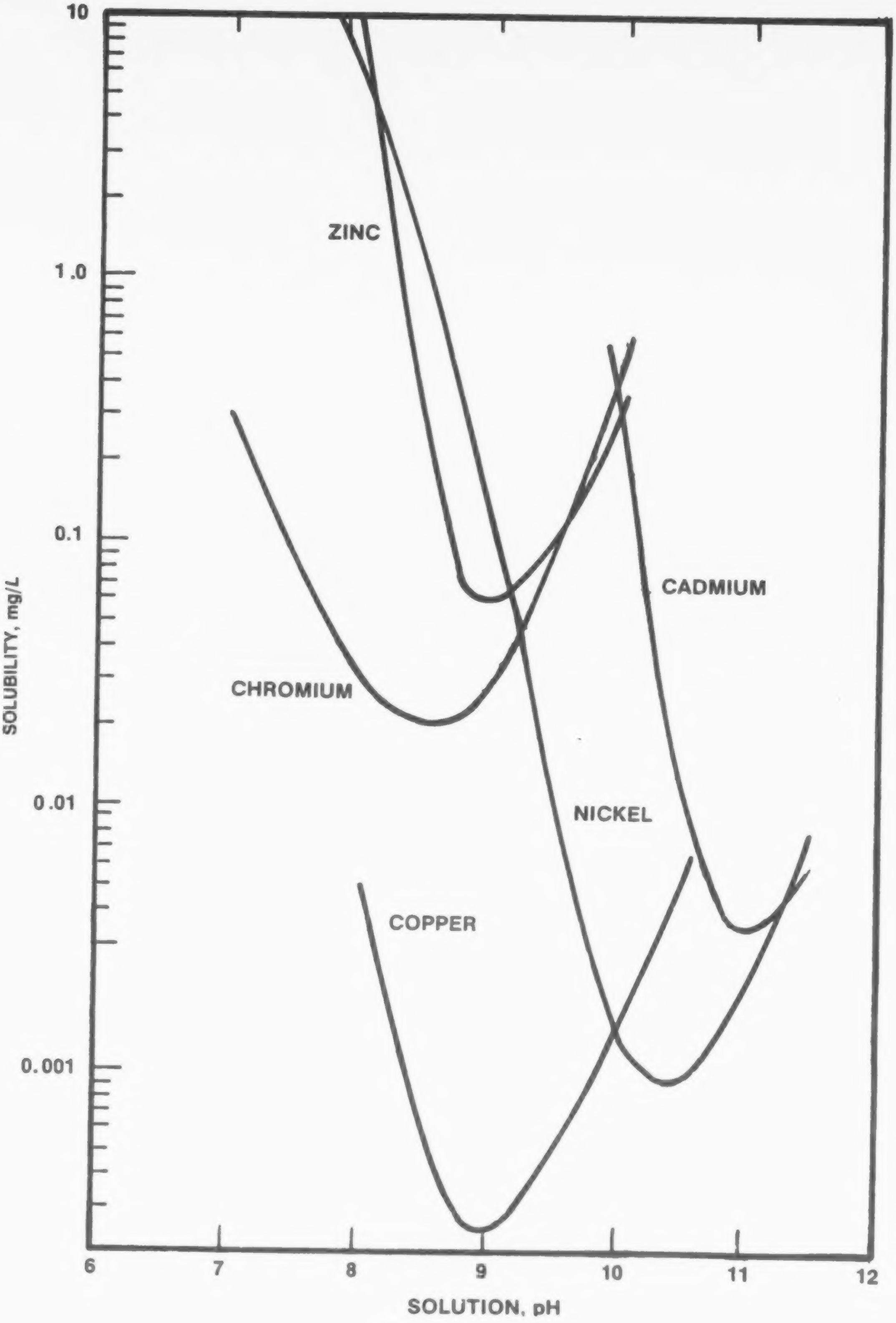


Fig. 6.74 Effects of pH on metal solubility

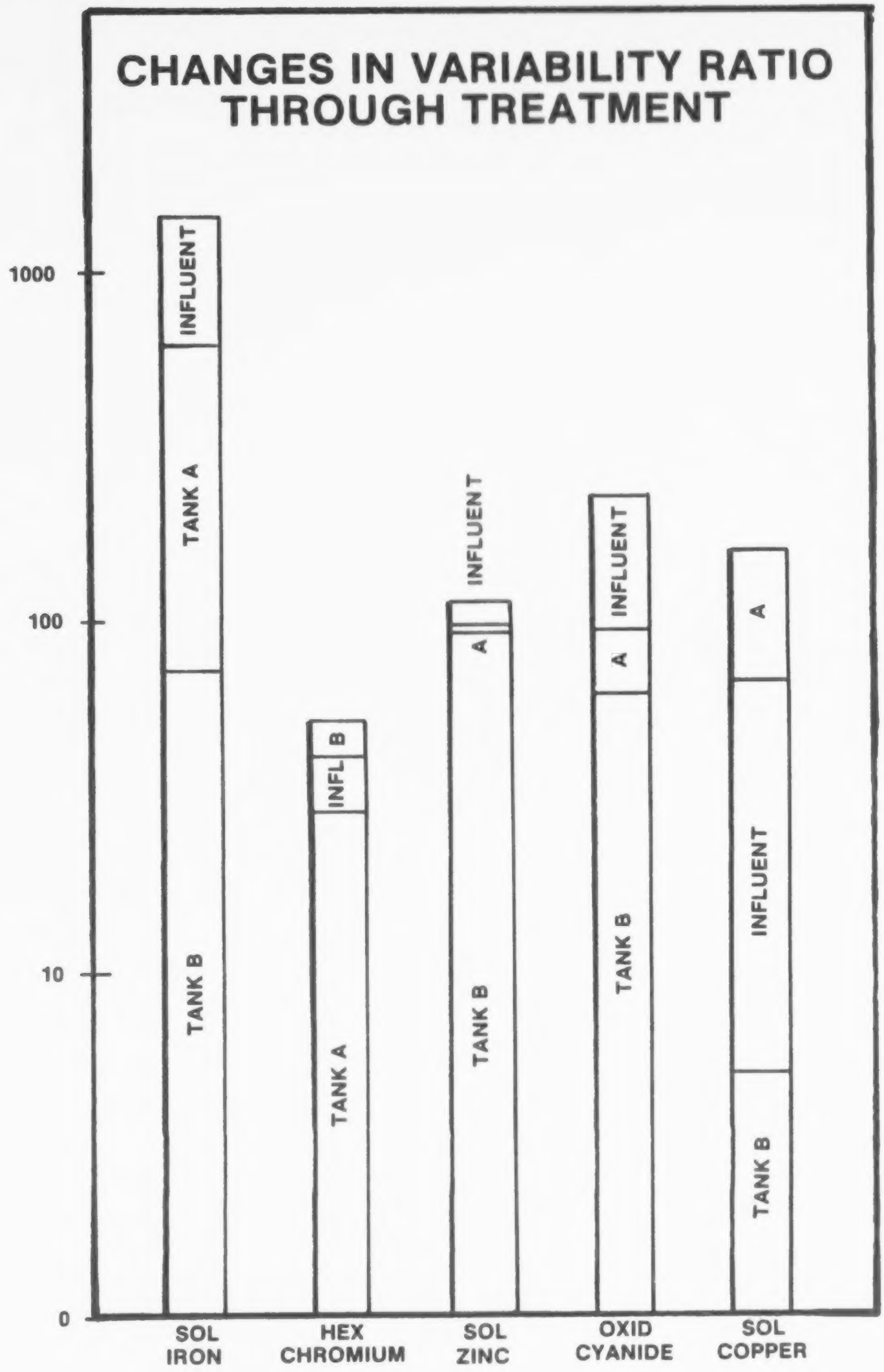


Fig. 6.75 Changes in chemical variability ratios during treatment

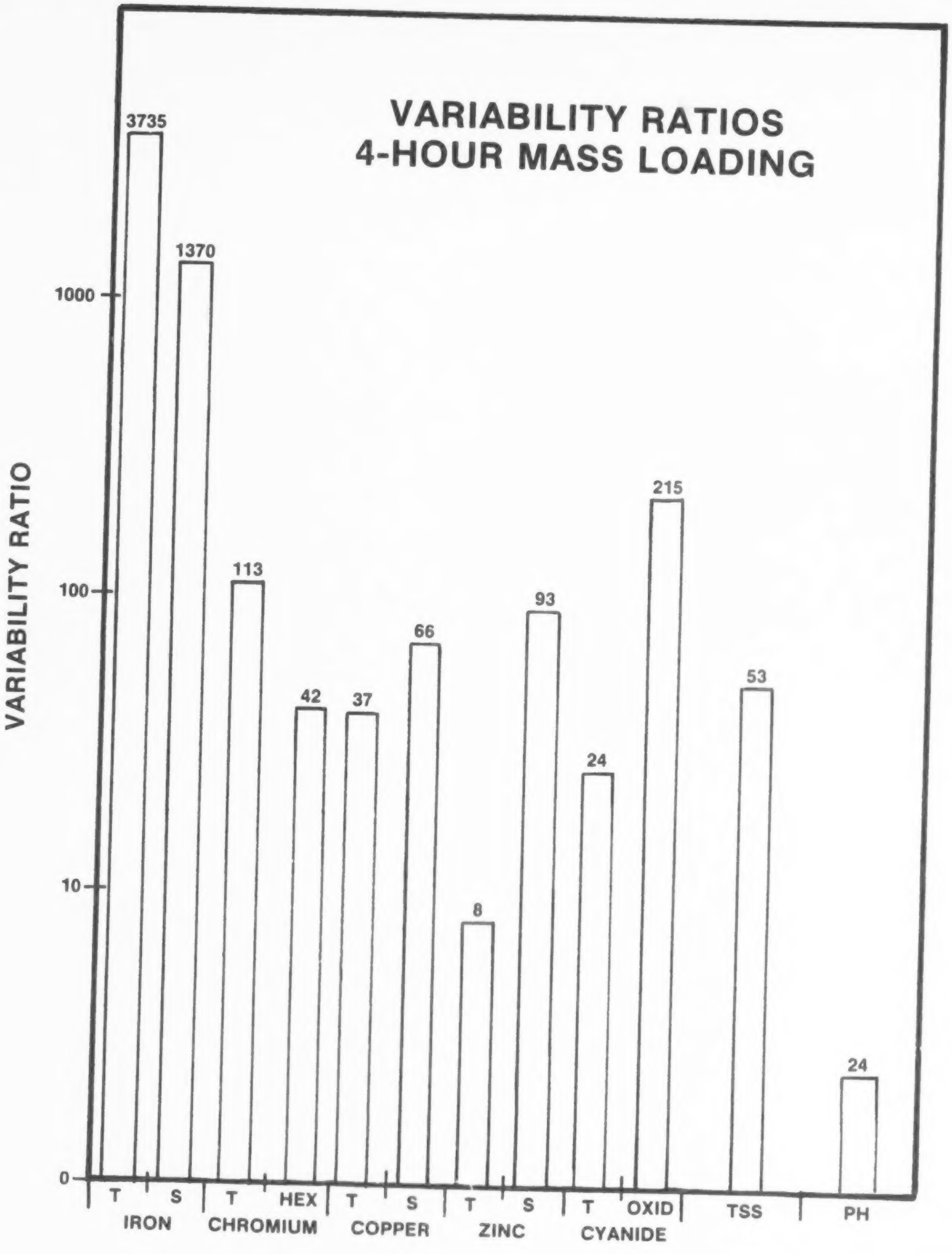
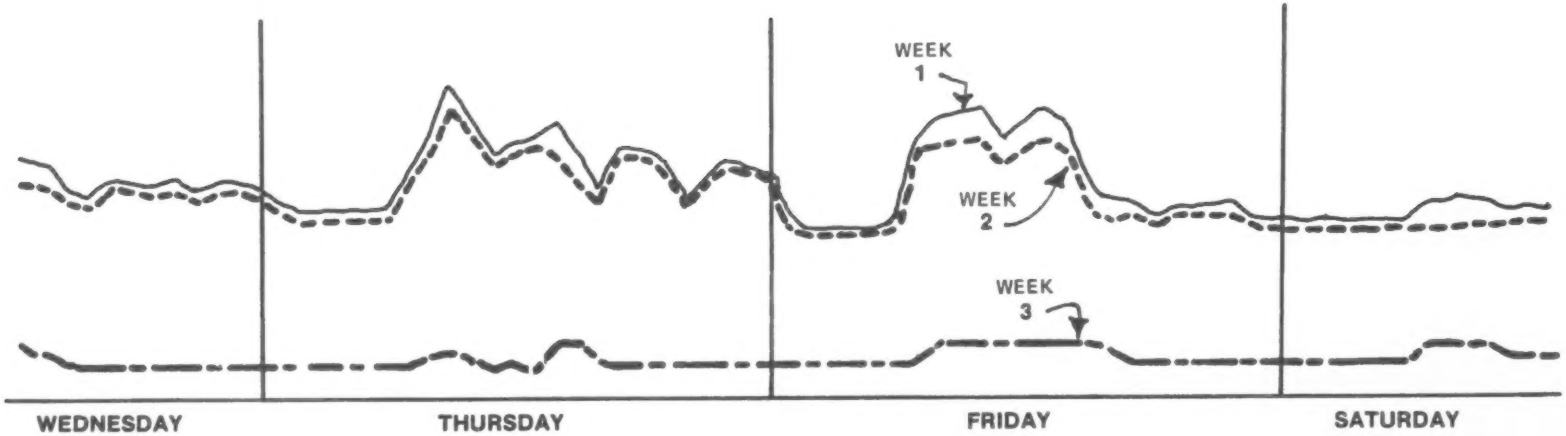


Fig. 6.76 Mass loading variability ratios



FLOW VARIATIONS AT TREATMENT PLANT

Fig. 6.77 Variations in flows at treatment plant

c. Sludge withdrawal rates should be adjusted to maintain:

   1. Proper sludge level in the solids conditioning tank.
   2. Proper sludge density of the sludge being removed.
   3. Proper torque reading of the rake drive.

d. Miscellaneous.

   1. Sludge withdrawal lines must be flushed after each use and possibly more often.
   2. Check oil levels on main drive gears at least once a week (sample and analyze oil at least once a year).
   3. Drain condensate and/or water from main drive gears at least once a week.
   4. Check drive belts and chains at least once a month.
   5. Check scum boxes at least once a week for plugging.
   6. Check associated safety equipment (guards, floatation rings, etc.) daily.

6.631 Sludge Thickener

a. Rake drive speed should be adjusted to maintain:

   1. Proper sludge level.
   2. Proper sludge density.
   3. Proper torque reading.
   4. Proper sludge mixing.

b. Automatic lifting device should be adjusted to maintain:

   1. Proper sludge level, density and mixing.
   2. Proper torque readings without setting off alarms or stalling the unit.

c. Miscellaneous.

   1. Sludge entry and withdrawal lines must be flushed after each use and possibly more often.
   2. Check oil levels on main drive gears at least once a week (sample and analyze oil at least once a year).
   3. Drain condensate and/or water from main drive gears at least once a week.
   4. Check drive belts and chains at least one a month.
   5. Check associated safety equipment (guards, floatation rings) daily.

6.632 Aeration Tank

a. Check operation and electrical current draw of floating aerator motor daily.

b. Check performance levels as required (temperature, DO levels, conversion of iron from soluble to insoluble, mixing).

c. Miscellaneous.

   1. Stop and *JOG*[21] reverse unit when:
      a. You see motor current fluctuations.
      b. You see rags or stringy material in the influent which may tangle in the impeller.
   2. Pull unit every 6 months:
      a. Lubricate motor.
      b. Be sure all nuts, bolts and impeller are secure.
   3. Lift aerator by the motor, not the float (to prevent cracking and eventual sinking of the float).
   4. Make harness for the aerator and float and attach to mooring lines.
      a. This will prevent cracking and sinking of the float if aeration tank goes dry or to a low level.
      b. Harness can be as simple as nylon straps under float and through mooring brackets to evenly distribute the weight.
   5. Check associated safety equipment (guards, floatation rings) daily.

6.633 Recycle Pump

a. Seal water lines should be checked at least daily.

b. Bearing temperature should be checked daily (by hand) and monthly by gage.

c. Gage readouts should be checked and verified as required.

d. Check air compressor reading and operation.

e. Miscellaneous.

   1. Exercise pneumatic valves at least monthly.
   2. Check filters and operation of pressure relief valve at least monthly.
   3. Change pump sequence at least monthly.
   4. Calibrate instruments at least monthly.
   5. Check wet well alarm levels quarterly.
   6. Check back-up water supply system:
      a. Lake pumps — check quarterly.
      b. City water cut-in valves — check operation at least monthly.
   7. Inspect and/or rebuild recycle pump yearly.
   8. Check associated safety equipment (guards, alarms) daily.

6.634 Vacuum Filters

a. Operate units as required, be sure units are recycled at least once a week.

b. Monitor vacuum reading, percent dry solids in and of filter cake and physical characteristics of the sludge and cake.

c. Lubricate, drain condensate, check belts and chains of all associated drive units as required.

d. Miscellaneous.

   1. Clean or repair spray nozzles as required.
   2. Clean, repair or replace filter cloth as required.

---

[21] *Jog. Stop-start unit to clear impeller or check loading or torque on unit.*

3. Check associated safety equipment prior to use of the equipment.

6.635 *Chemical Feed Systems*

- a. Acid/coagulant/polymer feed pumps
  - 1. Must be able to monitor feed rates.
    - a. Gage on storage tank.
    - b. Acid proof flow meter or calibration tap.
    - c. Visible discharge point.
  - 2. Miscellaneous.
    - a. If chemical feed is not automated, must be regulated to influent flow and solids concentration determined by jar test.
    - b. Check belt at least once a month.
    - c. Check oil at least monthly.
    - d. Clean pump head and check valves at least once per year, more often if recycled water is used as batch make-up water.
  - 3. Check associated safety equipment (face shields, rubber gloves, eyewash) daily.
- b. Polymer mixing unit.
  - 1. Dry polymers.
    - a. Fill hopper daily and record usage.
    - b. Check for proper cycling of mixing unit weekly.
    - c. Flush level sensing units weekly.
    - d. Calibrate feed rate weekly.
    - e. Clean up spilled product immediately.
    - f. Check associated safety equipment daily.
  - 2. Liquid polymers.
    - a. Check liquid polymer level, replenish as necessary, and record usage.
    - b. Check for proper cycling of mixing unit weekly.
    - c. Flush level sensing units weekly.
    - d. Calibrate feed rate weekly.
    - e. Clean up spilled product immediately.
    - f. Check associated safety equipment daily.
  - 3. Lime mixing units.
    - a. Fill hopper daily and record usage.
    - b. Check for proper operating and mixing daily.
    - c. Flush feed lines and clean ejectors daily or as needed.
    - d. Calibrate feed rate weekly.
    - e. Clean entire unit and adjust feed mechanism quarterly.
    - f. Maintain good housekeeping.
    - g. Check associated safety equipment (filters, vents, showers) daily.
  - 4. Caustic feed units.
    - a. Check reserve supply and record usage.
    - b. Check for proper operation daily.
    - c. Calibrate feed rate weekly.
    - d. Check associated safety equipment (rubber gloves, showers, eyewash) daily.

6.636 *Instrumentation*

- a. pH meters/recorders/controllers.
  - 1. Clean and calibrate units at least monthly.
  - 2. Spot check units with litmus paper on a regular basis and to confirm unusual readings.
  - 3. Have spare units ready to be installed, as needed.
- b. Flow meters.
  - 1. Clean and calibrate units at least monthly.
  - 2. Have back up system for monitoring flows, as required.
  - 3. Verify unusual flow reading if possible.
- c. Conductivity
  - 1. Clean and calibrate units at least monthly.
  - 2. Spot check units with portable units or with standard solutions on a regular basis and to confirm unusual reading.
- d. Other instrumentation.
  - 1. Clean and calibrate units as required.
  - 2. Have back up systems available. For example, tap for pressure gage by sensor for discharge pressure.
  - 3. Spot check unit as required.
- e. Other items.
  - 1. Keep all charts, strips and calibration records as required by your discharge permit.
  - 2. Have factory service personnel clean and calibrate all instruments yearly.

6.64 Aeration Tank

6.640 *Objectives*

- a. To oxidize the soluble iron content.
- b. To cool the water.
- c. To keep the tank's contents mixed.

6.641 *Operation*

- a. Wastewater at this plant is pumped from the pump stations to the aeration tank via three force mains.
- b. A mechanical floating aerator mixes and adds oxygen to the wastewater.
- c. After 20 minutes the aerated water leaves the tank by an overflow and proceeds to tank A by gravity.

6.642 *Initial Starting*

a. Turn power on (at motor control center #2 at Recycle Pump Station).

b. Turn upper current limit up all the way and turn lower current limit down all the way.

c. Go to aeration tank to be sure aerator is in water and that it is secured by the mooring cables.

d. Check for floating debris in or around aerator. Remove any debris.

e. Jog reverse aerator then press start button, be sure aerator starts.

f. Go back to motor control center #2 and check ammeter.

   1. If drawing 26-27 Amps reset upper limit to 35A.
   2. If drawing more than 27A:
      a. Return to tank and stop aerator.
      b. Jog reverse aerator several times to clean aerator propeller.
      c. Restart aerator.
      d. Recheck ammeter.
         1. If reading is still high, repeat procedure.
         2. If reading is normal, reset upper current limit to 35 Amps.
   3. If drawing less than 20 Amps:
      a. Be sure propeller hasn't spun off the aerator.
      b. Be sure aerator is floating in water and is not suspended in the air.
      c. Lower current limit is not connected, leave it at 0 Amps.

6.643 *Restarting Aerator*

a. Visually inspect unit.

   1. Be sure unit is in water and impeller or propeller is at proper submergence level.
   2. Fish out any floating solids.

b. Go to motor control center #2, be sure power is on.

c. Turn upper current limit up all the way and turn lower limit down all the way.

d. Return to aerator tank and jog reverse aerator several times to clean propeller.

e. Press start button, be sure aerator starts.

f. Go back to motor control center #2 and check ammeter.

   1. If drawing 26-27 Amps, reset upper limit to 35A.
   2. If drawing more than 27 Amps:
      a. Return to tank and stop aerator.
      b. Jog reverse aerator several times to clean aerator propeller.
      c. Restart aerator.
      d. Recheck ammeter.
         1. If reading is still high, repeat procedure.
         2. If reading is normal, reset upper current limit to 35 Amps.
   3. If drawing less than 20 Amps:
      a. Be sure aerator is floating in water.
      b. Be sure propeller hasn't spun off.
      c. Lower current limit is not connected, leave it at 0 Amps.

6.644 *Aerator Draining Procedures*

a. Turn unit off, disconnect power, lock it out.

b. Disconnect mooring cables from tank wall (attach ropes to cables for easier installation).

c. If not removing aerator from tank:

   1. Control flow from pump stations (lock out whenever possible).
      a. If done during plant shutdown, can turn off all pump stations as long as all water sources are off.
      b. If you can't turn off all pump stations indefinitely, station operators at pump stations #1, #2, and #3. At specified time have all three operators shut down pump stations (after they have pumped them down) for approximately 15 minutes.
   2. Open drain if allowed or pump into SCTA (Tank A).
   3. Be sure electrical cable does not become entangled as water level decreases.
   4. Have operators hold ropes which are attached to mooring cables, so you can guide aerator as water level decreases.
   5. Remove inspection manhole when water level is below it.
   6. Enter aeration tank at inspection manhole (wear hip boots).
   7. If pump stations can be left off for indefinite periods, you can use small pump to reduce water level farther; however, do not take it so low that aerator is hitting bottom.
   8. Remove any large particles of debris through manhole, smaller particles can be flushed through the drain.
   9. Make note of type of debris so that source can be located.
   10. If you have to activate pump station, remove operator from tank, pump down from pump station, turn off pump station, then re-enter tank.
   11. When complete, be sure area around and including drain are free from obstructions.
   12. Visually inspect aerator, clean prop and shaft if necessary, be sure unit is locked out.
   13. Get operator out of tank, close drain, or pull pumps, then put inspection cover back on.
   14. Start pump stations, let tank refill.

15. Guide aerator by using ropes attached to mooring cables.
16. When tank is full, reopen drain to flush out drain line.
17. When water starts overflowing to SCTA, re-attach mooring cables.
18. After visual check, turn on power and start aerator.

d. If removing aerator from tank, lock unit out.
   1. Pull aerator to platform using mooring cables.
   2. Attach choker to two eyebolts on aerator motor (do not lift by eyebolts on platform).
   3. Remove aerator, being sure that electrical cable does not become entangled.
   4. Inspect and clean aerator (keep aerator suspended, do not place it on ground).
      a. Check impeller, to be sure it is tight.
      b. Check tightness of all nuts.
      c. Have electrician lubricate motor.
      d. Check for cracks in the float.
      e. Install the power cable.
   5. Clean out tank as described in #3, if necessary.
   6. When aerator tank is clean and full, replace aerator being sure not to entangle or damage electrical cable.
   7. When water starts overflowing, re-attach mooring cables.
   8. After visual check, turn on power and start aerator.
   9. If aerator hops when started, reverse the rotation of the motor.

e. Plan on desludging aerator once a year, minimum.
   1. Follow instruction under Section 28.644, "Aerator Draining Procedures."
   2. If possible obtain sludge sample prior to desludging to determine where to put sludge.
   3. Clean and inspect valves in force mains at aeration tank.

6.645 Safety

a. While on tank platform:
   1. Be sure chain is up and secure.
   2. Watch out for burp (water bubbling up onto platform).
   3. Check pH at aeration tank; if extremely high or low, postpone work (if possible) until pH approaches 7.
   4. Watch your step when on tank or obtaining samples.
   5. Use caution when obtaining samples and always wash hands afterward.
   6. If you must go into an area that may be or is a confined space, be sure to follow the Confined Space Entry Procedures.
   7. If you feel light headed, nauseous or smell unknown fumes, leave area and get into fresh air.
   8. When using sampling equipment, beware of electrical shock.
   9. Hold onto your safety helmet, equipment and railings during windy periods.

b. If you have to work near or above water:
   1. Have at least one person as a "backup."
   2. Have a flotation device handy.
   3. Use a lifeline, if necessary.
   4. Use a boat, if necessary.
   5. Be able to swim.
   6. Do not have heavy tools in pockets or in belt.
   7. Be sure of footing.
   8. Be sure all necessary equipment is locked out, tagged and tried before working on a unit.
   9. Never start unit when pieces of material or the impeller could be thrown out by centrifugal force.
   10. Don't stand on aerator float while it is in the water.

6.646 Troubleshooting

a. Aerator won't restart.
   1. Check upper and lower current limits and put at their extremes.
   2. Check ammeter to be sure indicator isn't stuck on current limit indicator.

b. Running light is on but it looks like it is not operating.
   1. If there is a small current drain, the impeller has probably fallen off.
   2. Remove aerator, check for impeller in shroud, put impeller back on (use locklite) and reset aerator.

c. Unit keeps tripping out.
   1. You are probably getting rags or plastic on impeller.
      a. Jog reverse unit to clear impeller.
      b. Locate source of material and stop it from entering collection system.
   2. Current limit is set too close to operating current.
      a. Move upper limit to 35A.
      b. Keep lower limit on zero.
      c. Or can keep upper limit on 50A.
   3. Other electrical problems.

d. Water level goes below overflow line during plant shutdown.
   1. Pump station check valve leaking.
      a. Turn off manual valves at tank to determine which pump station it is.
      b. Listen for check valve clatter at that pump station.
   2. Drain is leaking or not closed.

6.65 Tank A (SCTA)

6.650 Objectives

a. To allow contact and mixing of wastewater and coagulating chemicals.

b. To allow sufficient time for the waste material to settle out.

c. To provide clarified water for reuse in the plant.

6.651 Operation

a. The turbine mixer unit constantly spins counter clockwise to mix the wastewater and chemicals.

b. The clarifier rake arms run continuously (clockwise) to "rake" the sludge to the center of the tank, to be pumped out.

6.652 Starting the Drive Units

a. Starting the rake.

1. Be sure the power is on at motor control center #1 (main disconnect on, control switch (start-stop) on start, and speed indicator on 25%).
2. Go to SCTA and press start button (be sure the stop lock is off).
3. Be sure rake travels in a clockwise direction (if not, shut unit down immediately and reverse motor).
4. If possible, start unit at high speed and turn down to approximately 20 percent as torque builds up on mechanism indicator.
5. Watch the torque meter and note the highest reading.
    a. If torque goes to 50, then SCTA rake drive overloading alarm sounds.
    b. If torque goes to 90, then the electrical circuit is opened and stops the rake mechanism.
6. If the torque meter electrically shuts the unit down:
    a. Wait until the torque settles down to a lower number and try to restart. (See — starting procedure for rake drive torque-out.)
    b. Manually and physically reverse rotate the motor or pulley until the torque is reached. (Be sure the unit is locked and tagged out and beware of rotation induced by torque already present on the rake arms.)
    c. By repeating item #2, you may create a "runway" for the arms allowing them to come up to speed and break through the sludge.
    d. To keep torque as low as possible, have the motor at the lowest speed possible.
    e. Can try an air or *WATER LANCE*[22] in front of the rake arms or extended flushing of the sludge line.
    f. Can try increasing the turbine speed.
    g. If all else fails, you must dewater the tank and physically remove the sludge. Getting the rake operating again is of prime importance; depending on sludge level and condition you may have from 2 to 12 hours to repair the rake before the sludge "hardens" to prevent the rake from moving.

WARNING: Never physically retain the torque meter or reverse the rotation of the rake arm. This will cause damage to the rake arms and the drive assembly and will cause a complete shutdown of the facility to repair the damage.

7. The rake drive should be running 24 hours a day. If the oil skimmer (attached to the rake arm) is not moving, notify the proper personnel at once. The less time the unit is down, the greater the chance of restarting it.

b. Starting the turbine mixer.

1. Be sure the power is on and the stop locks are off.
2. Reduce the vari-drive speed to the minimum (if it's not already there) as soon as the motor is started (note the original speed settings).
3. Go to SCTA and press the start button.
4. Slowly increase speed to the original setting over a five-minute period.

c. Stopping the turbine mixer.

1. Reduce the speed to the minimum over a five minute period (note the original speed).
2. Press the stop button.

6.653 Interpeting What You See

a. SCTA reaction well, what to look for:

1. See turbine mixer rotating and stirring the water.
2. See floc forming in the water from the chemical addition
    a. Want to see good sized solid floc (black lines seem to divide mixing zones in the tank).

b. Don't want to see:

1. Pinpoint floc. Causes:
    a. No or inadequate polymer feed.
    b. No or inadequate dose of iron salt.
    c. High or low pH movement or changes.
    d. Inadequate mixing (turbine).
    e. Inadequate sludge compaction and removal (rake).
    f. "Clean" influent (no solids or chemicals to react with to form large floc).
2. Large bulky fluffy floc.
    a. High or low pH level.
    b. Dispersant dumped into system.
    c. Too much polymer (large overdose).
    d. Inadequate mixing.

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[22] *Water Lance. A pipe on the end of a water hose that is used to hydraulically jet out solids.*

3. Oil on reaction well surface.
    a. Indicates large quantity was dumped into system.
    b. Find source and eliminate.
    c. Oil may cause either item #1 or #2.

6.66 Tank B (SCTB)

6.660 Objectives

a. To further improve water quality prior to discharge.
b. To remove chromium, copper and other metals by pH control.

6.661 Operation

a. Same as for SCTA except chemical upstream is lime or caustic.
b. Refer to SCTA Operation.

6.67 Sludge Thickener

6.670 Objectives

a. To mix sludges from Tank A and Tank B.
b. To thicken the sludge before it is pumped to vacuum filters.

6.671 Operation

a. This tank contains two drive units.
    1. Rake drive unit.
        a. To mix and help thicken sludge.
        b. To draw sludge to the center where it can be pumped out.
    2. Rake lifting unit.
        a. To raise and lower the rake arms.
        b. To maintain constant sludge thickness.

b. Starting the drive units.
    1. Turn on the power at motor control center #1 for both rake and rake lift units.
    2. Go to tank and put rake lift unit switch into down (automatic) position.
    3. Be sure that stop locks are off, then start rake drive.
    4. Rake drive should start immediately and lifting device will operate automatically as neeeded.
    5. If the torque goes above 60, the sludge thickener rake overload alarm will sound.
    6. If the torque goes above 90, the rake drive unit will shut down.
    7. If unit stops because of too much torque:
        a. Wait until torque reduces to lower number and try to restart.
        b. Manually put lift unit switch into up position to raise rake arms above the sludge.
        c. *NEVER* restrict or force the torque arm.
        d. Can recirculate sludge in tank using vacuum filter feed pumps. This will "soften" the sludge.
        e. Can open flush lines to break up the sludge.
        f. Pump all the sludge you can to vacuum filter to reduce level in the tank.
    8. Lift unit operates automatically by torque readings.
        a. If torque is below 15, the rake arms are lowered into the sludge.
        b. If torque is above 40, the rake arms are raised.
        c. Normal operating range is 20 to 40.

6.68 Operation of Processes

6.680 Normal Operations

a. Try to monitor sludge blanket. It should be approximately 6 feet at the center of the reaction well.
b. Monitor torque; try not to let it get above 30 at any time during normal operation.
c. Use ammeter on rake motor as a backup indicator of load on the rake arms.
d. Pump out sludge as required to maintain sludge blanket and torque.
e. Sample faucets on the side of the tanks can be used to determine sludge levels.
f. Keep scum box free of debris or it may plug or it may catch and stall the rake arm.
    1. Turn scum box oil line off each night to prevent oil pit overflow.
    2. Open valve each morning.
    3. Start oil pit pump each morning, if it's not in automatic operation.
g. SCTB Valve is used to control the amount of water discharged into Tributary 5A and in effect the level of the wet well.
    1. The valve should be in auto at all times.
    2. The valve should control the wet well level at approximately 10.25 feet with steady and smooth effluent discharge.
    3. The valve will not close completely in auto (to prevent freeze up to the valve).
    4. The valve will close upon the loss of the wet well signal.

6.681 Troubleshooting

a. Rake drive is down.
    1. Determine the problem (no power, broken belt, etc.).
    2. Repair the problem or put on spare unit as soon as possible.
    3. Getting the rake operating again is of prime importance; depending on the sludge level and condition you may have from 2 to 12 hours to repair the rake before the sludge "hardens" to prevent the rake from moving.
    4. See rake starting procedures.

6.682 Interpreting What You See

a. See Section 6.653, "Interpreting What You See," for SCTA reaction well, what to look for.

b. SCTA sedimentation zone.

1. Floc blooms (floc masses rising to the surface of the water.)

a. Caused by:

1. Rake speed too high.

2. pH fluctuations. Locate problem, neutralize.

3. Thermal currents. Locate problem and eliminate.

4. Air entrapment. Air bubbles from aerator, DO, or other sources lifting sludge.

5. Short circuiting in tank. Flow problems due to design, flow rate or structural problems.

6. Low sludge bed. No "filtering" of floc through previously formed sludge. Problem should be confined to perimeter of reaction well.

7. Dispersants. Floc should be equally distributed throughout tank.

2. Oil sheen on surface.

a. Sign of large oil spill or dump. Trace it down and clean up.

b. Sign of pH fluctuations, breaking oil free.

6.683 Sludge Quality

a. Should be of a muddy consistency.

b. Should be 10-15 percent dry solids (SCTA) or 5-10 percent dry solids (SCTB) during normal operating conditions.

c. SCTA sludge is normally brown, smooth and not gritty.

d. SCTB sludge is normally light brown, smooth, not gritty, thinner and fluffier.

e. Sludge thickener sludge should be brown, heavy, thicker and approximately 20 percent and up dry solids.

f. All sludge lines and pumps *MUST BE FLUSHED*.

g. SCTA sludge line *MUST BE FLUSHED* 20 minutes daily.

6.684 Upset Conditions

a. Check existing conditions.

1. pH. Look for fluctuation or oddity which may have triggered problem.

a. Locate source and type of material.

1. Get sample of material.

2. Get sample of recycled or discharged water.

3. Usual problem areas:

a. South Wire Mill Pickle Lines.

b. North Conditioning Pickle Line.

c. Boiler House — acid regeneration of water softeners.

d. For extremely low fluctuations check concentrated acid storage tanks.

b. Check chemical feeders.

1. Check power supply.

2. If it's in automatic sequence, be sure it is cycling properly.

3. Be sure hoppers/tanks are full.

4. Check strength of chemicals.

a. Specific gravity of $FeCl_3$.

b. Percent polymer in holding tank.

5. Check pump discharges for actual flow.

6. Be sure all valves on pump discharge are open.

c. Check for abnormal conditions.

1. Excessive city water inputs.

2. Large acid or caustic dumps.

3. Oil spills into system.

4. Spill or dump of chemical into the system.

5. Check for production problems (breakdowns, planned maintenance, abnormal operations).

d. Resolving the upset.

1. Jar test to determine optimum chemical dosages.

2. Adjust chemical feeders.

3. Set-up samplers at W.W.T.P. or at pump stations as required.

a. Determine abnormal constituents or concentrations.

b. Use discrete samplers to have visual indication of progress.

4. Obtain help from consultants and chemical representatives.

5. When problem is solved, try to pinpoint cause and duplicate it in jar tests. Develop measures to prevent reoccurrence and be sure they are implemented.

6.685 Safety. See Section 6.645, Safety.

CHAPTER 6. INDUSTRIAL WASTE TREATMENT PROCESSES

APPENDIX: LABORATORY PROCEDURES

I. Influent and Effluent Tests

A. Chemical Oxygen Demand (COD)

A measure of the oxygen-consuming capacity of inorganic and organic matter present in wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/*L* during a specific test. Results are not necessarily related to the biochemical oxygen demand (BOD) because the chemical oxidant may react with substances that bacteria do not stabilize. See Chapter 16, "Laboratory Procedures and Chemistry," Volume II, *OPERATION OF WASTEWATER TREATMENT PLANTS,* for test procedures.

B. Turbidity

Turbidity units, if measured by a nephelometric (reflected light) instrumental procedure, are expressed in nephelometric turbidity units (NTU). Those turbidity units obtained by other instrumental methods or visual methods are expressed in Jackson turbidity units (JTU) and sometimes as Formazin turbidity units (FTU). The FTU nomenclature comes from the Formazin polymer used to prepare the turbidity standards for instrument calibration. Turbidity units are a measure of the cloudiness of water.

II. Status of Activated Carbon

A. Abrasion Number (Ro-Tap)

The abrasion number of granular carbon is a measure of the resistance of the particles to degrading on being mechanically abraded. This number is measured by contacting a carbon sample with steel balls in a pan on a Ro-Tap machine. The abrasion number is the ratio of the final average (mean) particle diameter to the original average (mean) particle diameter (determined by screen analysis) times 100.

B. Abrasion Number (NBS)

Similar to A above except different equipment is used.

C. Apparent Density

The weight per unit volume of a homogenous activated carbon. To assure uniform packing of a granular carbon during measurement, a vibrating trough is used to fill the measuring device.

D. Decolorizing Index

Molasses solution is treated with different weights of a standard carbon of known Decolorizing Index. The optical densities of the filtrate are measured and plotted with the known Decolorizing Index values to obtain a standard curve. A molasses solution is then treated with pulverized activated carbon of unknown decolorizing capacity. The optical density of the filtrate is measured and the Decolorizing Index is determined from the standard curve.

E. Effective Size and Uniformity Coefficient

Effective size is the size of the particle that is coarser than 10 percent, by weight, of the material. That is, it is the size sieve which will permit 10 percent of the carbon sample to pass but will retain the remaining 90 percent. Effective size is usually determined by the interpolation of a cumulative particle size distribution.

Uniformity coefficient is obtained by dividing the sieve opening in millimeters which will pass 60 percent of a sample by the sieve opening in millimeters which will pass 10 percent of the sample. These values are usually obtained by interpolation on a cumulative particle size distribution.

F. Hardness Number

The hardness number is a measure of the resistance of a granular carbon to the degradation action of steel balls in a pan in a Ro-Tap machine. This number is calculated by using the weight of granular carbon retained on a particular sieve after the carbon has been in contact with steel balls. This is the Chemical Warfare Service (CWS) test.

G. Iodine Number

The iodine number is the milligrams of iodine adsorbed by one grain of carbon at an equilibrium filtrate concentration of 0.02*N* iodine. The number is measured by contacting a single sample of carbon with an iodine solution and extrapolating to 0.02*N* by an assumed isotherm slope. Iodine number can be correlated with ability to adsorb low molecular weight substances.

H. Methylene Blue Number

The methylene blue number is the milligrams of methylene blue adsorbed by one gram of carbon in equilibrium with a solution of methylene blue having a concentration of 1.0 mg/*L*.

I. Moisture

Moisture is the percent by weight of water adsorbed on activated carbon.

J. Molasses Number

The molasses number is calculated from the ratio of the optical densities of the filtrate of a molasses solution treated with a standard activated carbon and the activated carbon in question. This is a test method of a Pittsburgh Activated Carbon Company.

K. Sieve Analysis (Dry)

The distribution of particle sizes in a given sample is obtained by mechanically shaking a weighed amount of material through a series of test sieves, and determining the quantity retained by or passing given sieves.

L. Total Ash of Regenerated Carbon

The total ash of a carbon is a measure of the amount of the inorganic matter present. This test is accomplished by a combustion process in which organic matter is converted to carbon dioxide and water at a controlled temperature to prevent decomposition and volatilization of inorganic substances as much as is consistent with complete oxidation of organic matter.

TESTS FOR MEASURING THE STATUS OF ACTIVATED CARBON

Test procedures outlined in this appendix were taken from *PROCESS DESIGN MANUAL FOR CARBON ADSORPTION*, Appendix B, Technology Transfer, U.S. Environmental Protection Agency, October 1973.

A. Abrasion Number (Ro-Tap)

The Abrasion Number of carbon defines the resistance of the particles to degradation by the action of steel balls in a Ro-Tap machine, and is calculated as the percentage change in mean particle diameter.

1. Equipment

Ro-Tap — Sieve Shaker, Fisher Scientific Catalog No. 4-906.

Sieves — U.S. Standard A.S.T.M. Sieves, 8-inch diameter, full height.

Hardness Testing Pan Assembly — See Section F, Hardness Testing, Figures A-4 and A-5.

Steel Balls — Ten (10) one-half-inch diameter and ten (10) three-quarter-inch diameter smooth steel balls.

2. Procedure

Make a dry sieve analysis of 100 grams of the material to be tested and save the screen fractions. The sieve analysis is to be done exactly as specified in the Westvaco Dry Sieve Analysis procedure except that the shaking time in the Ro-Tap is increased to ten (10) minutes. Sieves should be selected according to the nominal particle size of the carbon as set forth in attached Table A-1. Calculate the mean particle diameter of the sample from the sieve analysis (see Table A-2).

TABLE A-1 SUGGESTED SIEVES TO BE USED FOR SCREEN ANALYSIS

Nominal Sieve Size	U.S.S. (N.B.S.) Sieve Numbers
12 × 40	12, 16, 20, 30, 40, Pan
14 × 40	14, 16, 20, 30, 40, Pan
4 × 30	8, 12, 16, 20, 30 Pan
10 × 30	10, 12, 16, 20, 30 Pan
12 × 30	12, 16, 20, 30 Pan

Recombine the fractions from the sieve analysis and place in the special hardness pan with 20 steel balls (see Figures A-4 and A-5 of hardness pan and equipment list). Shake the pan assembly on the Ro-Tap machine for 20 minutes with the tapper in operation.

At the end of the 20 minutes, remove the steel balls, make another sieve analysis and calculate the mean particle diameter.

3. Calculations

$$\text{Abrasion Number} = \frac{\text{Final mean particle diameter}}{\text{Original mean particle diameter}} \times 100$$

TABLE A-2 FACTORS FOR CALCULATING MEAN PARTICLE DIAMETERS*

U.S.S. Sieve Number	Mean Opening mm	U.S.S. Sieve Number	Mean Opening mm
+4	5.74		
4 × 6	4.06		
6 × 8	2.87		
		4 × 8	3.57
8 × 10	2.19		
10 × 12	1.84		
		8 × 12	2.03
12 × 14	1.55		
14 × 16	1.30		
		12 × 16	1.44
16 × 18	1.10		
		16 × 20	1.02
18 × 20	0.92		
20 × 25	0.78		
		20 × 30	0.72
25 × 30	0.65		
30 × 35	0.55		
		30 × 40	0.51
35 × 40	0.46		
40 × 45	0.39		
		40 × 50	0.36
45 × 50	0.33		
		50 × 60	0.27
50 × 70	0.25		
		60 × 70	0.23
70 × 80	0.19		
		70 × 100	0.18
80 × 100	0.16		

* The mean particle diameter of each fraction is assumed to be midway between the sieve opening in millimeters through which the material has passed and the sieve opening in millimeters on which the material was retained.

The mean particle diameter of the whole sample is computed by multiplying the weight of the fraction by the respective mean sieve openings, summing these weighted values and dividing by total weight of material caught on the sieves and pan. The following example for a 12 × 30 mesh sample illustrates the method of calculation.

Sieve No.	Weight Retained On Sieve, g	Mean Opening, mm	Weighted Average
On 12	1.5	2.03[a]	3.0
16	25.1	1.44	36.1
20	50.2	1.02	51.2
30	22.5	0.72	16.2
Pan	1.1	0.00[b]	0
	100.4		106.5

$$\text{Mean Particle Diameter} = \frac{106.5}{100.4} = 1.061 \text{ mm}$$

---

[a] Assuming this material would pass the No. 8 sieve (or generally the next larger sieve in the square root of two series).

[b] Material caught on the pan is not considered in calculating the Mean Particle Diameter.

B. Abrasion Number (NBS)

The apparatus consists essentially of an inverted T-shaped stirrer turning rapidly in a cylindrical vessel containing the activated carbon. The clearance at the ends of the stirrer and bottom are the only critical dimensions. The speed of the shaft is 855 ± 15 rpm. (Obtained with a 2:1 reduction by V belt from a 1,750 rpm motor 1/10 horsepower or larger.) A simple frame for holding the drive motor and bearing container assembly is also required.

(Apparent Density)

Procedure

1. Prepare a sample of activated carbon by the recommended sampling procedures having a volume of 250 to 300 ml.
2. Obtain a sieve analysis by the recommended sieving procedure. Discard the fractions through No. 70 sieve and recombine all sieve fractions coarser than No. 70 and place in hardness tester.
3. Operate the tester for 1 hour ± 1 minute.
4. Repeat the sieve analysis for the stirred mixture.
5. Calculate the percentage through No. 70 and record as the percent dust formation.
6. Calculate the average particle size, D, before and after stirring from the sieve analysis by means of the following relationship:

   $$D = \frac{\Sigma W_i D_i}{\Sigma W_i}$$

   where W is the weight of a sieve fraction, and the particle diameter, D, is obtained as the arithmetic average of opening of sieves above and below the fraction.
7. The percentage reduction in particle size is the decrease in average particle size calculated as a percentage of the original particle size.
8. Since this test abrades particles in proportion to their size, divide both percentage reduction in particle size and percentage dust formation by particle size (mm) before stirring in order to reduce both results to a standard 1 mm particle size.

C. Apparent Density

The apparent density is defined as the weight of carbon per unit volume expressed in grams per cubic centimeter or pounds per cubic foot.

1. Equipment

Vibrator Feeders — See Figure A-1.

Cylinder — 100 ml A.S.T.M. Graduated Cylinder

2. Procedure

Dry an adequate sample of the carbon to be tested at 140 degrees C for one (1) hour or 110 degrees C for three (3) hours. Place a representative sample of the dried carbon into the reservoir funnel of the apparent density apparatus. Material which flows prematurely into the graduated cylinder is returned to the reservoir funnel.

Fill the tared graduated cylinder to the 100 ml mark at a uniform rate so that filling time is not less than 100 seconds nor more than 133 seconds. The rate can be adjusted by changing the slope of the metal vibrator and/or raising or lowering the reservoir funnel. A powerstat can be used to regulate the speed of the vibrator, thus regulating the rate of filling of the cylinder. Determine the weight of the carbon in the graduated cylinder to the nearest tenth of a gram (0.1 gram).

3. Calculations

$$\text{Apparent Density, gm/cc} = \frac{\text{Weight of Activated Carbon}}{100}$$

4. Dimensions of Funnels and Vibrator

Metal Vibrator	1-¾-inches wide 3-½-inches long ¾-inch deep
Reservoir Funnel	Top Diameter 3-inches Bottom Diameter 1-⅝-inches Overall Height 4-inches Height to flared top 3-¼-inches
Feed Funnel	Top Diameter 3-½-inches Bottom Diameter 15/16-inch Overall Height 4-inches Height to flared top 1-½-inches

D. Decolorizing Index

Molasses solution is treated with different weights of a standard carbon of known Decolorizing Index. The optical densities of the filtrate are measured and plotted with the known Decolorizing Index values to obtain a standard curve. A molasses solution is then treated with pulverized activated carbon of unknown decolorizing capacity. The optical density of the filtrate is measured and the Decolorizing Index is determined from the standard curve.

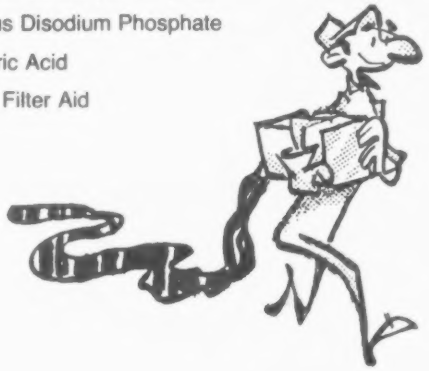
1. Reagents and Equipment

Blackstrap Molasses — This molasses is available only through the Chemical Division, Westvaco Corporation, as selection is required to obtain molasses which provides reproducible data from year to year.

Anhydrous Disodium Phosphate

Phosphoric Acid

Supercel Filter Aid



Standard D. I. Carbon — Small quantities of primary standard carbon are available from the Chemical Division, Westvaco Corporation.

Filter Cloth — A chain cloth, 32-inches wide, made by T. Shriver and Company, Harrison, New Jersey.

Electric Hot Plate — The hot plate is a Type H, 120 volts, 550 watts, made by Precision Scientific Company. This hot plate is used without the refractory top.

Klett-Summerson Colorimeter — A No. 54 green filter and a 10 ml Klett-Summerson absorption tube (12.5 mm

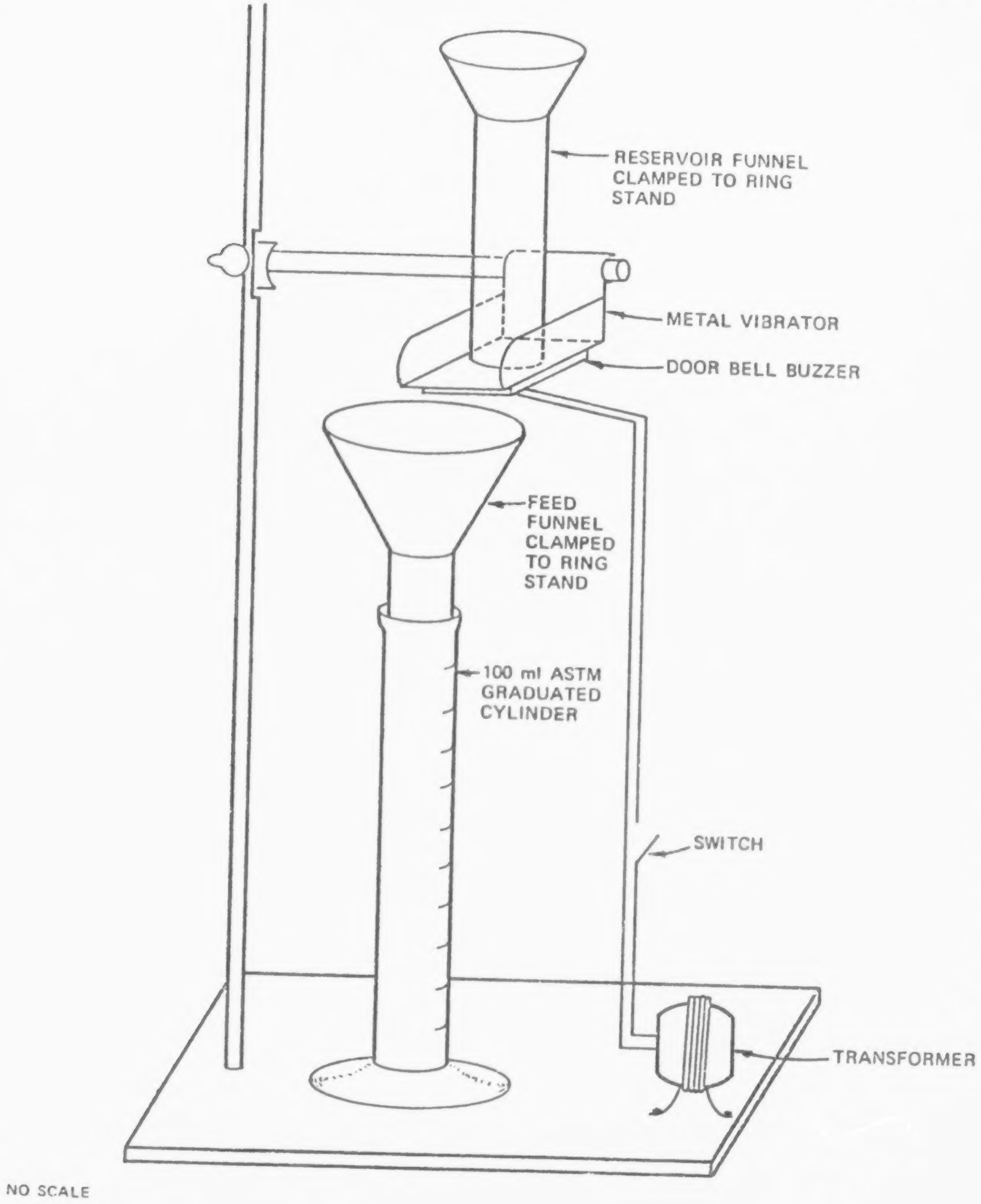

RESERVOIR FUNNEL CLAMPED TO RING STAND
METAL VIBRATOR
DOOR BELL BUZZER
FEED FUNNEL CLAMPED TO RING STAND
100 ml ASTM GRADUATED CYLINDER
SWITCH
TRANSFORMER
NO SCALE

Fig. A-1 Apparent density test apparatus

(Decolorizing Index)

light path) are used for reading the samples. The instrument is zeroed using distilled water.

The instrument should give approximately the following reading when using a 0.5 normal potassium dichromate ($K_2Cr_2O_7$) solution:

0.5 Normal Potassium Dichromate	Klett-Summerson Reading
20 Percent Dilution	155
60 Percent Dilution	280
100 Percent Dilution	350

Return instrument pointer to near zero after each reading.

Analytical Balance — Sensitivity to 0.5 milligram.

Spex-Mixer Mill — No. 800 Spex-Mixer Mill and No. 8001 Grinding Vials, Spex Industries, Inc., 3880 Park Avenue, Metuchen, New Jersey.

Filter Paper — Whatman No. 5, 15 cm.

2. Preparation of Solutions

Buffer Solution — (8X) — 104 grams anhydrous disodium phosphate (Na_2HPO_4) or equivalent weight of crystalline phosphate, are dissolved in about 500 milliliters of warm distilled water. When the phosphate is completely dissolved, make up to one liter with distilled water. Acidify with concentrated reagent-grade phosphoric acid to ph 6.5 ± 0.1. For preparation of larger quantities, multiples of these weights and volumes may be used.

Molasses Solution — Dilute 40 grams of the blackstrap molasses in about 50 ml (or amount necessary) of distilled water (approximately 25 degrees C). Add 125 ml of buffer solution, dilute to one liter with chilled distilled water (approximately 4 degrees C) and mix thoroughly. (Solution will be about 13 degrees C.) However, if the molasses solution is to be used immediately the distilled water does not need to be chilled before using.

For preparations of larger quantities, multiples of these weights and volumes can be used.

A Buchner funnel fitted with a filter cloth, is precoated by slurrying Supercel filter aid with a portion of the blackstrap molasses solution and filtering. Use sufficient Supercel filter aid to provide a cake approximately one-half inch thick. After precoating, change funnel to a clean filter flask. Pour the solution, to which a small amount of Supercel has been added. The entire solution is then filtered through the filter aid cake. (If necessary, this solution should be refiltered until it is clear.) If this solution is not to be used immediately, it must be refrigerated (at about 4 degrees C).

3. Preparation of Standard Curve

1. Weigh accurately (± 0.001 gram) the following weights of the ground* Standard D. I. carbon (dried at 140 degrees C for one (1) hour or 110 degrees C for three (3) hours) into 150 ml beakers: 0.200, 0.300, 0.400, 0.500, 0.600, 0.700, 0.800, 0.900 and 1.00 gram.
2. Measure 50 ml of the molasses solution, using a graduated cylinder, and reading the bottom of the meniscus.
3. Add 10 to 20 ml of the molasses solution to the weighed carbon. Swirl the contents of the beaker gently until the carbon is completely wetted. Use the remaining portion of the molasses solution to wash down the sides of the beaker.
4. Place the beaker on the hot plate and bring the sample to a boil (the solution should be brought to boiling in less than 200 seconds). Boil for 30 seconds and then remove sample from hot plate.
5. Filter immediately by gravity using a Whatman No. 5, 15 cm filter paper (or equivalent). Allow all of the samples to filter.
6. Allow filtrate to cool to room temperature (approximately 25 degrees C).
7. Read the color of the samples, using the Klett-Summerson Colorimeter.
8. To prepare the Standard Curve, plot the Klett-Summerson readings of the samples (from Step 1) versus the assigned Decolorizing Index Numbers (listed in the following table) on semilogarithmic, 1 cycle × 70 divisions graph paper.

Weight of Standard D. I. Carbon	Assigned Decolorizing Index Number
0.200	6.5
0.300	8.6
0.400	11.2
0.500	14.0
0.600	16.9
0.700	19.9
0.800	23.0
0.900	27.0
1.00	30.8

Draw a straight curve line through these points. (See Figure A-2). A new standard curve will need to be prepared for a molasses solution which has been stored at 4 degrees C for longer than 16 hours.

4. Preparation of Samples to be Tested

1. Weigh 0.460 ± 0.001 gram of the dried ground carbon sample to be tested, and transfer to a 150 ml beaker.
2. Follow Steps 2 through 7 under Preparation of Standard Curve.
3. The D. I. of the carbon is determined from the Standard Curve.

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* A ground sample is obtained by placing a 5.5±0.5 gram sample of dried carbon in a Spex-Mixer Mill containing 64 one-fourth inch diameter smooth steel balls until 90±5 percent will pass a 325 mesh screen (by wet screen analysis).

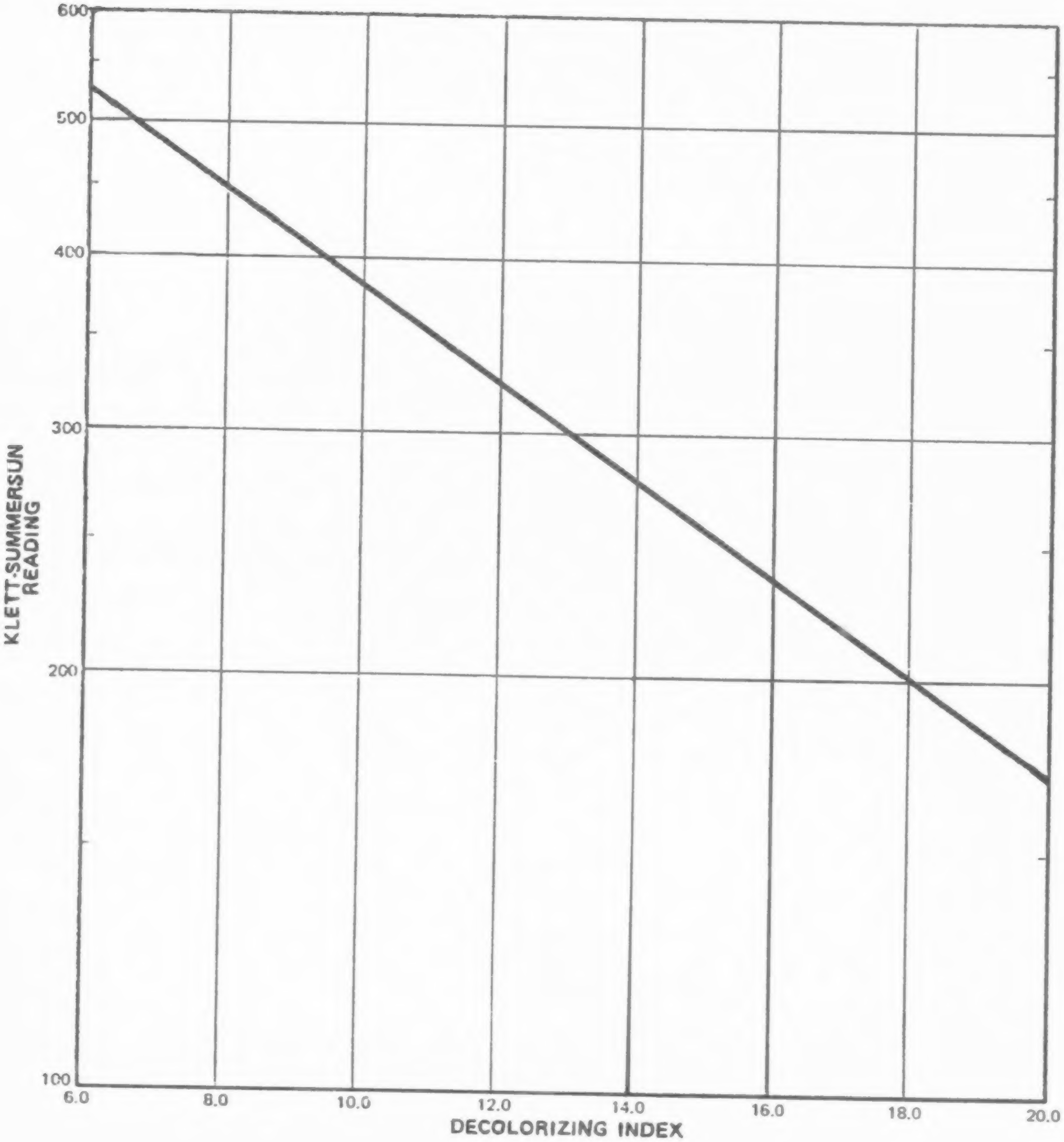

Fig. A-2. Example of standard curve

E. Effective Size and Uniformity Coefficient

The Effective Size is defined as the size of the particle that is coarser than 10 percent, by weight, of the material. This size is usually determined by the interpolation of a cumulative particle size distribution.

The Uniformity Coefficient is obtained by dividing the sieve opening in millimeters which will pass 60 percent of a sample by the sieve opening in millimeters which will pass 10 percent of the sample. These values are usually obtained by interpolation on a cumulative particle size distribution.

1. Procedure

1. Run a standard sieve analysis as outlined in the sieve analysis (dry) test procedure.
2. From the percentage retained on each sieve, the cumulative percent passing each sieve can be obtained (see Table A-3).
3. On probability × logarithmic paper, plot the sieve opening in millimeters on the ordinate, or vertical scale, versus the cumulative percent passing each sieve on the abcissa, or horizontal scale (see Figure A-3).
4. The Effective Size is determined as the millimeter opening at which 10 percent passes on the cumulative percent passing scale.
5. The Uniformity Coefficient is determined by dividing the millimeter opening at which 60 percent passes by the millimeter opening at which 10 percent passes.

TABLE A-3 EXAMPLE EFFECTIVE SIZE AND UNIFORMITY COEFFICIENT DETERMINATION

Sieve No.	Sieve Opening, Millimeters	Wt. Retained on Sieve, grams	% Retained	Cumulative % Passing
12	1.680	0.3	0.3	99.7
16	1.190	20.7	20.9	78.8
20	0.840	49.4	49.8	29.0
30	0.590	22.0	22.2	6.8
40	0.420	6.5	6.6	0.2
Pan		0.2	0.2	
		99.1	100.0	

Effective Size: 0.66

Uniformity Coefficient: $\frac{1.04}{0.66} = 1.575$

F. Hardness Number (CWS)

A sample of carbon of a pre-selected mesh size is subjected to the action of steel balls on a Ro-Tap machine. The resistance of the carbon to degradation by this action is termed the Hardness Number.

1. Equipment

Ro-Tap — Sieve Shaker, Fisher Scientific Catalog No. 4-906.

Sieves — U.S. Standard Sieve Series, 8-inch diameter, full height sieves.

Hardness Testing Pan Assembly — See Figures A-4 and A-5.

2. Procedure

1. Weigh 50.0 grams of prepared size material (see Note 1) and place in a special hardness testing pan (see Figure A-4).
2. Place 15 one-half-inch diameter and 15 three-eighth-inch diameter smooth steel balls in the hardness testing pan.
3. Nest the hardness testing pan with a bottom receiving pan below, a half-height blank pan and iron sieve cover above, and place assembly on the Ro-Tap machine for 30 minutes with the tapper in operation.
4. At the end of the 30-minute period, remove the steel balls on a No. 4 sieve and transfer the sample to a sieve nested on a bottom receiving pan (see Note 1).
5. Place the sieve assembly on the Ro-Tap machine for 3 minutes with the tapper in operation.

3. Notes on Method

1. Selection of Special Sieve Sizes for Various Grades of Carbon
   a. For 4 × 8, 4 × 10, 6 × 8, 6 × 12 and 6 × 16 mesh carbons, prepare 50.0 grams of 6 × 8 mesh material by shaking approximately 100 grams of original sample for 3 minutes on a Ro-Tap machine, using the Nos. 6 and 8 sieves. Repeat, if necessary, until 50.0 grams are obtained. Use a No. 12 sieve for the final screening step.
   b. For 8 × 20, 8 × 30, 10 × 30, 12 × 30 and 12 × 40 mesh carbons, prepare 50.0 grams of 12 × 16 mesh material and use a No. 20 sieve for the final screening step.
   c. For 4 × 6 mesh carbon, prepare 50.0 grams of 4 × 6 mesh material and use a No. 8 sieve for the final screening step.
   d. For 8 × 14 mesh carbon, prepare 50.0 grams of 8 × 12 material and use a No. 16 sieve for the final screening step.

G. Iodine Number

The Iodine Number is defined as the milligrams of iodine adsorbed by one gram of carbon when the iodine concentration of the residual filtrate is 0.02 normal.

1. Reagents and Equipment

Hydrochloric Acid, 5 percent weight — To 550 ml of distilled water add 70 ml of reagent-grade concentrated hydrochloric acid (HCl).

Sodium Thiosulfate, 0.1 normal — Dissolve 25 grams of reagent-grade sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) in one (1) liter of freshly boiled distilled water. Add a few drops of chloroform to minimize bacterial decomposition of the thiosulfate solution. Standardize the thiosulfate solution against 0.100 normal potassium biniodate ($KH(IO_3)_2$). Prepare the 0.1000 normal $KH(IO_3)_2$ using primary standard quality $KH(IO_3)_2$

(Effective Size and Uniformity Coefficient)

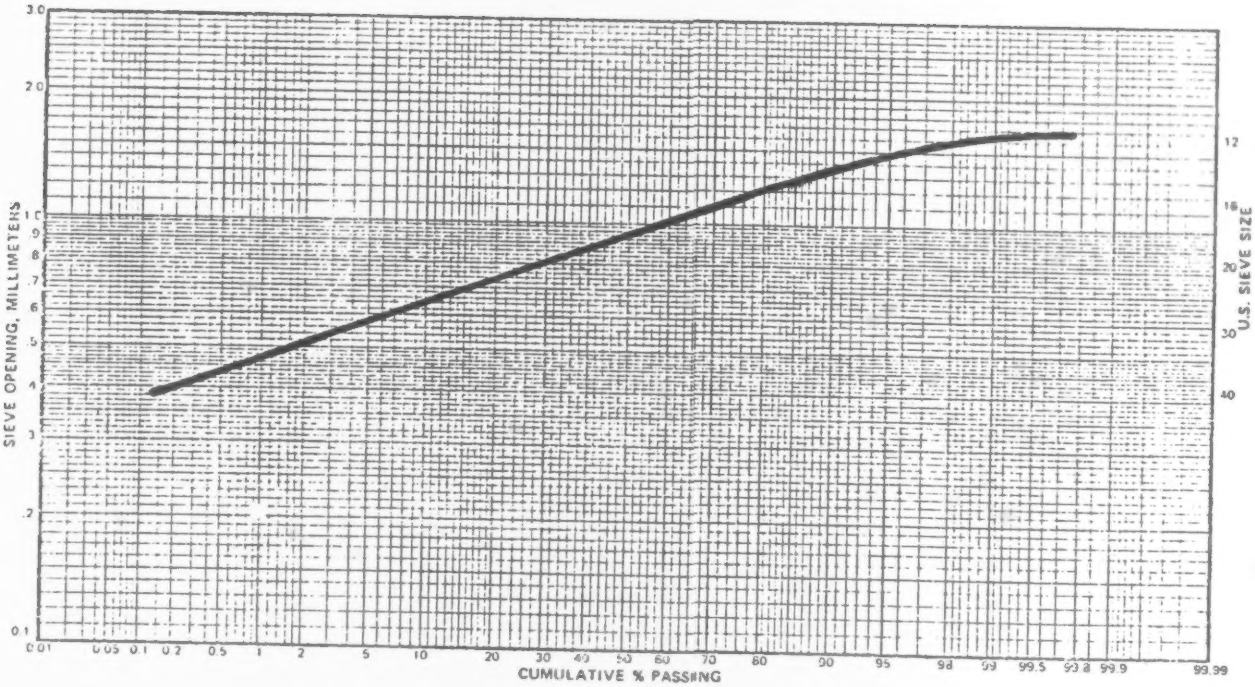

Fig. A-3. Cumulative particle size distribution curve

(For determination of Effective Size and Uniformity Coefficient)

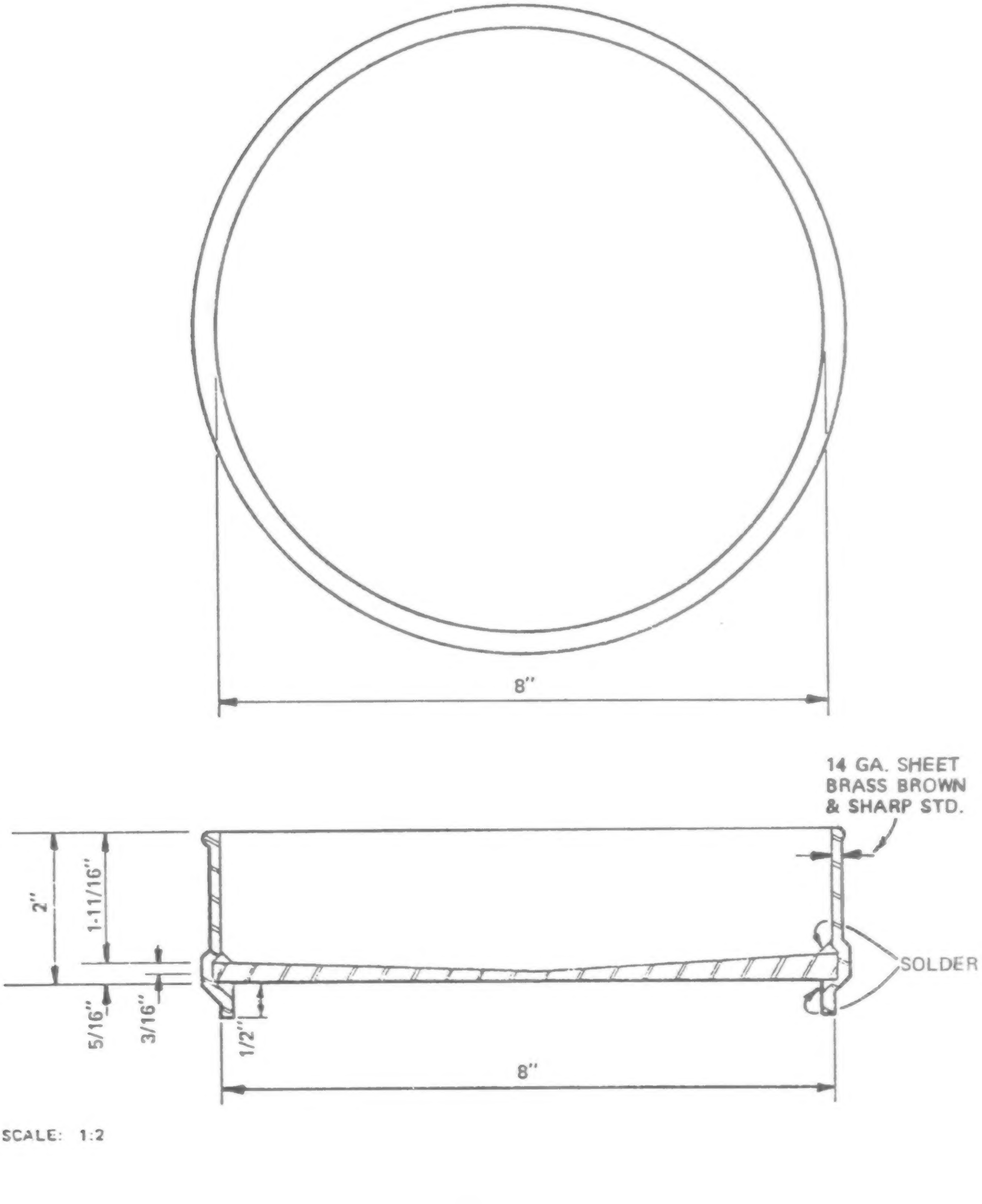
8"
14 GA. SHEET
BRASS BROWN
& SHARP STD.
SOLDER
2"
1-11/16"
5/16"
3/16"
1/2"
8"
SCALE: 1:2

Fig. A-4. Testing pan for determining hardness and abrasion

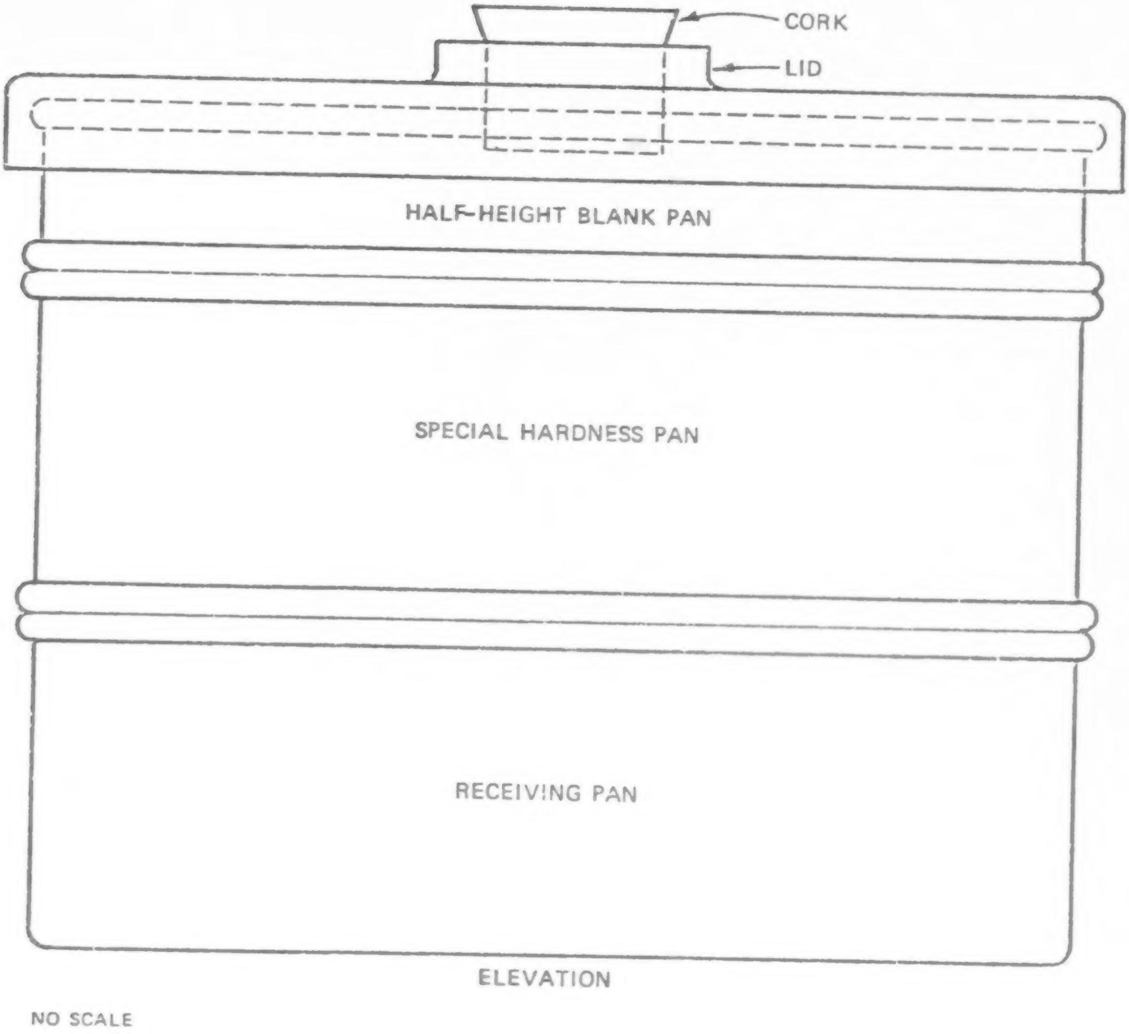
CORK
LID
HALF-HEIGHT BLANK PAN
SPECIAL HARDNESS PAN
RECEIVING PAN
ELEVATION
NO SCALE

Fig. A-5. Arrangement of Ro-Tap pans for hardness and abrasion test which has been dried overnight at 105 degrees C and cooled in a desiccator. Weigh 3.249 grams $KH(IO_3)_2$ and make-up to exactly one liter in a volumetric flask with distilled water. Store in a glass-stoppered bottle.

To 80 ml of distilled water add, with constant stirring, one ml of concentrated sulfuric acid (H_2SO_4), 10 ml of 0.1000 $KH(IO_3)_2$ solution and approximately one gram of potassium iodide (KI). Titrate the mixture immediately with the thiosulfate solution adding 2-3 drops of starch solution when the iodine fades to a light yellow color. Continue the titration by adding the thiosulfate dropwise until a drop produces a colorless solution. Record the volume of titrate used.

$$\text{Normality of sodium thiosulfate} = \frac{1000}{\text{ml of } Na_2S_2O_3 \text{ consumed}}$$

Iodine Solution — Dissolve 12.7 grams of reagent-grade iodine (I_2) and 19.1 grams of potassium iodide in a small quantity, approximately 20 ml, of distilled water. (If excess water is used, materials will not go into solution.) Dilute to one (1) liter in a volumetric flask with distilled water. Store in a glass-stoppered bottle in a dark place or use in a dark bottle. To standardize the iodine solution, pipet 25.0 ml into a 250 ml Erlenmeyer flask and immediately titrate with the 0.1 normal thiosulfate solution. Add 2-3 drops of starch solution near the endpoint and continue titrating until solution is colorless. Record the volume of titrant used.

$$\text{Normality of iodine solution} = \frac{\text{ml of } Na_2S_2O_3 \text{ used} \times \text{normality } Na_2S_2O_3}{25}$$

Starch Solution — To 2.5 grams of starch (potato, arrowroot, or soluble), add a little cold water and grind in a mortar to a thin paste. Pour into one (1) liter of boiled distilled water, stir, and allow to settle. Use the clear supernatant. Preserve with 1.25 grams of salicylic acid per one (1) liter of starch solution.

Filter Paper — Whatman Folded No. 2V, 10.5 cm.

Spex-Mixer Mill — No. 8000 Spex-Mixer Mill and No. 8001 Grinding Vials, Spex Industries, Inc., 3800 Park Avenue, Metuchen, New Jersey.

2. Procedure

Grind a representative sample of carbon in a Spex-Mixer Mill (usually 70 seconds) until 90 ± 5 percent will pass a 325 mesh sieve (by wet seive analysis). Load the Spex-Mixer Mill with a 5.5 ± 0.5 gram sample and use 64 one-fourth inch diameter smooth steel balls. An adequate sample of the pulverized carbon should then be dried at 140 degrees C for one (1) hour, or 110 degrees C for three (3) hours. A moisture balance can also be used.

Weigh 1.000 gram of the dried pulverized carbon (see Note 1) and transfer the weighed sample into a dry, glass-stoppered, 250 ml Erlenmeyer flask. To the flask add 10 ml of 5 percent by weight HCl acid and swirl until the carbon is wetted. Place the flask on a hot plate, bring contents to boil and allow to boil for only 30 seconds.

After allowing the flask and contents to cool to room temperature, add 100 ml of standardized 0.1 normal iodine solution to the flask. Immediately stopper flask and shake contents vigorously for 30 seconds. Filter by gravity immediately after the 30-second shaking period through Whatman No. 2V filter paper. Discard the first 20 or 30 ml of filtrate and collect the remainder in a clean beaker. Do not wash the residue on the filter paper.

Mix the filtrate in the beaker with a stirring rod and pipet 50 ml of the filtrate into a 250 ml Erlenmeyer flask. Titrate the 50 ml sample with standardized 0.1 normal sodium thiosulfate until the yellow color has almost disappeared. Add about 1 ml of starch solution and continue titration until the blue indicator color just disappears. Record the volume of sodium thiosulfate solution used.

Notes on Procedure

1. The capacity of a carbon for any adsorbate is dependent on the concentration of the adsorbate in the medium contacting the carbon. Thus, the concentration of the residual filtrate must be specified, or known, so that appropriate factors may be applied to correct the concentration to agree with the definition. The amount of sample to be used in the determination is governed by the activity of the carbon. If the residual filtrate normality (C) is not within the range 0.008*N* to 0.035*N* given in the Iodine Correction Table A-4, the procedure should be repeated using a different weight of sample.

2. The potassium iodide to iodine weight ratio must be 1.5 to 1 in the standard iodine solution.

Calculation

$$\text{Iodine Number} = \frac{X}{m} D$$

$$\frac{X}{m} = \frac{A - (2.2B \times \text{ml of thiosulfate solution used})}{\text{Weight of sample, grams}}$$

$$C = \frac{N_2 \times \text{ml thiosulfate solution used}}{50}$$

X/m = mg iodine adsorbed per gram of carbon

N_1 = Normality of iodine solution

N_2 = Normality of sodium thiosulfate solution

A = $N_1 \times 12693.0$

B = $N_2 \times 126.93$

C = Residual filtrate normality

D = Correction factor (obtained from Table A-4)

H. Methylene Blue Number

The Methylene Blue Number is defined as the milligrams of methylene blue adsorbed by one gram of carbon in equilibrium with a solution of methylene blue having a concentration of 1.0 mg per liter.

1. Reagents and Equipment

Methylene Blue — Zinc-free, American Cyanamid Company. Dry the methylene blue to constant weight. Prepare solutions of 20.00 and 1.00 g/*L* concentrations.

Colorimeter — An instrument such as the Klett-Summerson Industrial Model (for colorimetric analysis).

Variable-Speed Shaker — Will Scientific Catalog No. 23690 with Box Carrier Catalog No. 23696.

Filter Paper — Whatman No. 3, Qualitative.

Spex-Mixer Mill — No. 8000 Spex-Mixer Mill and No. 8001 Grinding Vials, Spex Industries, Inc., 3880 Park Avenue, Metuchen, New Jersey.

TABLE A-4 IODINE CORRECTION FACTOR (D)

Residual Filtrate Normality (C)	.000	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009
.0080	1.1625	1.1613	1.1600	1.1575	1.1550	1.1538	1.1513	1.1500	1.1475	1.1463
.0090	1.1438	1.1425	1.1400	1.1375	1.1363	1.1350	1.1325	1.1300	1.1288	1.1275
.0100	1.1250	1.1238	1.1225	1.1213	1.1200	1.1175	1.1163	1.1150	1.1138	1.1113
.0110	1.1100	1.1088	1.1075	1.1063	1.1038	1.1025	1.1000	1.0988	1.0975	1.0963
.0120	1.0950	1.0938	1.0925	1.0900	1.0888	1.0875	1.0863	1.0850	1.0838	1.0825
.0130	1.0800	1.0788	1.0755	1.0763	1.0750	1.0738	1.0725	1.0713	1.0700	1.0688
.0140	1.0675	1.0663	1.0650	1.0625	1.0613	1.0600	1.0588	1.0575	1.0563	1.0550
.0150	1.0538	1.0525	1.0513	1.0500	1.0488	1.0475	1.0463	1.0450	1.0438	1.0425
.0160	1.0413	1.0400	1.0388	1.0375	1.0375	1.0363	1.0350	1.0333	1.0325	1.0313
.0170	1.0300	1.0288	1.0275	1.0263	1.0250	1.0245	1.0238	1.0225	1.0280	1.0200
0.180	1.0200	1.0188	1.0175	1.0163	1.0150	1.0144	1.0138	1.0125	1.0125	1.0113
.0190	1.0100	1.0088	1.0075	1.0075	1.0063	1.0050	1.0050	1.0038	1.0025	1.0025
.0200	1.0013	1.0000	1.0000	0.9988	0.9975	0.9975	0.9963	0.9950	0.9950	0.9938
.0210	0.9938	0.9925	0.9925	0.9913	0.9900	0.9900	0.9888	0.9875	0.9875	0.9863
.0220	0.9863	0.9850	0.9850	0.9838	0.9825	0.9825	0.9813	0.9813	0.9800	0.9788
.0230	0.9788	0.9775	0.9775	0.9763	0.9763	0.9750	0.9750	0.9738	0.9738	0.9725
.0240	0.9725	0.9708	0.9700	0.9700	0.9688	0.9688	0.9675	0.9675	0.9663	0.9663
.0250	0.9650	0.9650	0.9638	0.9638	0.9625	0.9625	0.9613	0.9613	0.9606	0.9600
.0260	0.9600	0.9588	0.9588	0.9575	0.9575	0.9563	0.9563	0.9550	0.9550	0.9538
.0270	0.9538	0.9525	0.9525	0.9519	0.9513	0.9513	0.9506	0.9500	0.9500	0.9488
.0280	0.9488	0.9475	0.9475	0.9463	0.9463	0.9463	0.9450	0.9450	0.9438	0.9438
.0290	0.9425	0.9425	0.9425	0.9413	0.9413	0.9400	0.9400	0.9394	0.9388	0.9388
.0300	0.9375	0.9375	0.9375	0.9363	0.9363	0.9363	0.9363	0.9350	0.9350	0.9346
.0310	0.9333	0.9333	0.9325	0.9325	0.9325	0.9319	0.9313	0.9313	0.9300	0.9300
.0320	0.9300	0.9294	0.9288	0.9288	0.9280	0.9275	0.9275	0.9275	0.9270	0.9270
.0330	0.9263	0.9263	0.9257	0.9250	0.9250					

(Methylene Blue Number)

2. Procedure

Grind a representative sample of carbon in a Spex-Mixer Mill until 90 ± 5 percent will pass a 325 mesh screen (by wet screen analysis). Load the Spex-Mixer Mill with a 5.5 ± 0.5 gram sample and use 64 one-fourth inch diameter steel balls. An adequate sample of the carbon should then be dried at 140 degrees C for one (1) hour or 100 degrees C for three (3) hours.

Add 5.00 grams of pulverized carbon to a 250 ml Erlenmeyer flask (see Note 1). Add 80 ml of methylene blue solution (20 grams per liter) to the beaker. Shake at about 150 oscillations per minute for 20 minutes using a mechanical stirrer. Immediately after the stirring period, filter, through a Buchner funnel under vacuum, using Whatman No. 3 filter paper (see Note 2). Discard the first 10 to 15 ml of the sample filtrate and collect the remainder.

3. Colorimetric Analysis

Transfer the filtrate to a solution cell having a 40 mm effective depth and record the reading using a colorimeter with a green (540 mμ) color filter (see Note 4). Prepare a standard curve using methylene blue concentrations of 0.4, 1.0, 3.0, and 5.0 mg/*L* (see Note 3). Determine the concentration of methylene blue by reference to the standard curve (Table A-5). The methylene blue number is found by referring to Table A-6.

4. Notes on Procedure

1. The weight of sample taken is determined by the activity of the carbon. The 5.00 gram sample size is correct for carbons having methylene blue numbers ranging from 264 to 330. For carbons of higher activity, it will be necessary to use only a 4 gram sample while other carbons of lower activity will require from 6 to 8 grams to reduce the concentration of methylene blue in the filtrate reasonably close to that of the standards.
2. Prepare the filter beforehand by placing the filter paper in the funnel, wetting it thoroughly and removing excess water with the vacuum. Discard the water from the flask to prevent dilution of the test filtrate.
3. To prepare standards having methylene blue concentrations of 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 3.0 and 5.0 mg per liter, dilute 5.0 ml of the 1.0 gram per liter methylene blue solution to one liter with distilled water. Then transfer 4, 6, 8, 11, 15, 20, 30 and 50 ml of the resulting solution to separate 50 ml volumetric flasks and dilute to 50 ml with distilled water.
4. If the filtrate color is deeper than a reading corresponding to 5 mg/*L* on the standard curve, pipet 0.5, 1, 5, or 10 ml into a 50 ml volumetric flask and dilute to the 50 ml mark with distilled water. Determine the methylene blue concentration for the diluted sample and use the following formula to determine filtrate concentrations:

$$\text{Filtrate concentration, mg}/L = \frac{\text{Diluted concentration} \times 50}{\text{ml sample pipetted into volumetric flask}}$$

TABLE A-5 DILUTION CHART FOR METHYLENE BLUE DETERMINATION

Methylene Blue Concentration, mg/*L*

Color Standard	No. of ml of Filtrate Taken 50 ml	10 ml	5 ml	1 ml	0.5 ml
3	0.4	2.0	4.0	20.0	40.0
3-½	0.5	2.5	5.0	25.0	50.0
4	0.6	3.0	6.0	30.0	60.0
4-½	0.7	3.5	7.0	35.0	70.0
5	0.8	4.0	8.0	40.0	80.0
5-½	0.9	4.5	9.0	45.0	90.0
6	1.0	5.0	10.0	50.0	100.0
6-½	1.25	6.25	12.5	62.5	125.0
7	1.50	7.5	15.0	75.0	150.0
7-½	1.75	8.75	17.5	87.5	175.0
8	2.00	10.0	20.0	100.0	200.0
8-½	2.50	12.5	25.0	125.0	250.0
9	3.00	15.0	30.0	150.0	300.0
9-½	4.00	20.0	40.0	200.0	400.0
10	5.00	25.0	50.0	250.0	500.0

TABLE A-6 METHYLENE BLUE CORRECTION CHART

(mg Methylene Blue adsorbed per gram of carbon at a filtrate concentration of 1.0 mg/L)

Filtrate Concentration mg Methylene Blue/L	Methylene Blue Number				
	Sample Size				
	4 gm	5 gm	6 gm	7 gm	8 gm
0.4	416	333	277	238	208
0.5	414	331	276	236	207
0.6	410	328	273	235	205
0.7	408	327	272	234	204
0.8	407	326	271	233	203
0.9	406	325	270	232	203
1.0	405	324	270	232	202
1.2	402	322	268	230	201
1.5	399	319	266	228	200
1.75	398	318	265	227	199
2.0	396	317	264	226	198
2.5	394	315	262	225	197
3.0	391	313	261	224	195
3.5	388	311	259	223	194
4.0	387	310	258	222	193
4.5	386	309	257	221	193
5.0	385	308	256	220	192
6.0	384	307	256	220	192
6.25	382	306	255	219	191
7.0	381	305	254	218	191
7.5	380	304	253	217	190
8.0	380	304	253	217	190
8.75	378	303	252	216	189
9.0	377	302	251	216	189
10.0	376	301	250	215	188
12.5	374	299	250	213	187
15.0	371	297	248	212	185
17.5	370	296	247	212	185
20.0	368	295	246	211	184
25.0	365	292	243	209	184
30.0	363	291	242	208	182
35.0	361	289	241	207	181
40.0	360	288	240	206	180
45.0	358	287	239	205	179
50.0	357	286	238	204	179
60.0	355	284	237	204	178
62.0	353	283	236	203	177
70.0	352	282	235	202	176
75.0	351	281	234	201	175
80.0	351	281	234	201	175
87.5	350	280	233	200	175
90.0	350	280	233	200	175
100.0	348	279	232	199	174
125.0	346	277	231	198	173
150.0	344	275	229	197	172
175.0	342	274	228	196	171
200.0	341	273	227	195	170
250.0	338	271	226	194	169
300.0	336	269	224	192	168
400.0	332	266	222	190	166
500.0	330	264	220	188	165

(Molasses Number)

I. Moisture

Moisture is the percent, by weight, of water adsorbed on activated carbon.

1. Procedure

1. Dry an aluminum moisture dish (2-inches in diameter by ⅞-inch deep) and lid in an electric oven for thirty (30) minutes at 110 degrees C. Cool in a desiccator and weigh.
2. Weigh approximately 2 grams of carbon into the tared dish, recording the exact weight.
3. Place the dish containing the carbon (lid opened to allow the moisture to escape) in the oven and allow to dry either three (3) hours at 110 degrees C, or two (2) hours at 140 degrees C. Close lid tightly, remove from the oven, cool the dish in a desiccator and weigh.

An alternate method is to use a moisture balance.

2. Calculation

$$\text{Percent moisture} = \frac{\text{Loss in weight during drying, g}}{\text{Initial weight of sample, g}} \times 100\%$$

For example:

Weight of dish plus sample = 15.5543
Weight of dish = 13.5478
Weight of sample = 2.0065
Weight of dish plus dried sample = 15.4635
Loss of weight = .0906

$$\text{Percent Moisture} = \frac{.0908\ \text{g}}{2.0065\ \text{g}} \times 100\%$$

$$= 4.5\%$$

Values reported to the nearest 0.1 percent are satisfactory, i.e., in the above case, 4.5 percent.

J. Molasses Number

Molasses solutions are treated with pulverized activated carbon of unknown decolorizing capacity and with a standard carbon of known Molasses Number. The optical densities of the filtrates are measured and the Molasses Number of the unknown is calculated from the ratio of the optical densities and the standard value.

1. Reagents and Equipment

Standard Carbon — Small quantities of standard carbon are available from the Chemical Division, Westvaco Corporation.

Molasses Solution — Prepare by diluting 146 grams of blackstrap molasses with one (1) liter of distilled water. The weight of molasses to be used varies with the particular lot of molasses and is adjusted, if necessary, so that the standard carbon produces a filtrate with an optical density (percent transmission) of 0.38 to 0.42.

Any grade of commercial molasses which may be purchased will vary considerably in depth of color. The dilution of the initial solution to give the same final filtrate color with the standard carbon compensates for such variations. Once such an adjustment has been made on a given lot of molasses, the proper dilution may be made routinely. The molasses solution is stored in a refrigerator and any unused portion discarded after 24 hours.

A suitable grade of blackstrap molasses can be purchased from Refined Syrups, Yonkers, New York.

Spex-Mixer Mill — No. 8000 Spex-Mixer Mill and No. 8001 Grinding Vials, Spex-Industries, Inc., 3880 Park Avenue, Metchun, New Jersey.

Filter Paper Suspension — Prepare by mascerating 16 circles of Whatman No. 3, 7-cm filter paper in one (1) liter of distilled water.

Absorption Cell — Klett-Summerson, No. 902, 10-mm.

Immersion Plate — Klett-Summerson, No. 903, 7.5 mm.

2. Procedure

Grind a representative sample to carbon in a Spex-Mixer Mill until 90 ± 5 percent will pass a 325-mesh sieve (by wet sieve analysis). Load the Spex-Mixer Mill with a 5.5 ± 0.5 gram sample and use 64 one-fourth inch diameter smooth steel balls. An adequate supply of the carbon should then be dried at 140 degrees C for one (1) hour or 110 degrees C for three (3) hours. Weigh 0.46 gram portions of pulverized standard carbon of known decolorizing capacity and unknown carbon and transfer to separate 400 ml beakers. Add 50.0 ml of molasses solution to each beaker and stir until the carbon is thoroughly wetted.

Place the beakers on hotplate and allow to boil for 30 seconds from time boiling commences.

Immediately after boiling, filter the samples by vacuum through a Buchner funnel, using Whatman No. 3 filter paper which has been previously coated by filtering 50 ml of the filter paper suspension (see Note 1). Discard the first 10 to 15 ml of the sample filtrate and collect the remainder.

Using a 2.5 mm effective light path and a 425 $m\mu$ (blue) filter, compare the optical densities of the samples against distilled water in a Fisher Electrophotometer or other suitable instrument (see Note 2).

Notes on Procedure

1. The Buchner funnels and precoated filter paper should be prepared beforehand so that no delay is encountered in filtering the samples. Discard the filtrate from the filter paper suspension before filtering the samples.
2. Since the Fisher Electrophotometer is not equipped with 2.5 mm cells, the cell holder was modified to accommodate the 10-mm, Klett-Summerson cell. A 2.5 mm effective light path is obtained by placing the cell with a 7.5 mm glass immersion plate.

Calculations

$$\text{Molasses Number} = \frac{K \times B}{A}$$

K = Molasses Value of Standard Carbon
A = Optical Density of Filtrate from Test Carbon
B = Optical Density of Filtrate from Standard Carbon

K. Sieve Analysis (Dry)

The distribution of particle sizes in a given sample is obtained by mechanically shaking a weighed amount of material through a series of test sieves, and determining the quantity retained by or passing given sieves.

1. Equipment

Riffle, Jones Sample — Will Scientific Catalog No. L-23621

Ro-Tap — Sieve Shaker, Fisher Scientific Catalog, No. 4-906

Brush — For metal surfaces, brass wire bristle, Will Scientific Catalog No. 6916

Sieves — U.S. Standard A.S.T.M. Sieves, 8-inch diameter, full height

Balance having a sensitivity of 0.1 gram

2. Procedure

Reduce the sample to be tested to 100 grams by means of a riffle (see Note 1). Assemble the nest of desired sieves in order of decreasing size of opening, the sieve having the largest openings mounted on top. Place the 100.0 gram sample in the top sieve, install iron cover on top of the assembly and shake on the Ro-Tap machine for three (3) minutes with the tapper in operation (see Note 2). Weigh and report the percent of material retained on each sieve (see Notes 3 and 4).

Notes on Procedure

1. The sample is carefuly reduced by repeated passes through the riffle until the amount collected on one of the riffle pans is close to 100 grams. The entire contents of that pan are then emptied onto a balance accurate to 0.1 gram and weighed. No more than 5 grams should be added to, or taken from, the balance without additional riffling. For example, if the entire contents from the riffle pan weighed only 90 grams, the additional 10 grams should be obtained by riffling another sample down to an approximate 10 gram portion, after which the entire contents of that riffle pan are emptied onto the balance. Removing large quantities from the balance or adding large quantities from the sample stock without riffling will lead to erroneous results.
2. With sieving samples which are finer than 100 mesh, the shaking time must be increased. Use 10 minute intervals until less than 2 grams are collected in the receiving pan in a 10 minute interval.

3. The sieve should be lightly brushed with a brass wire bristle brush to free particles held in the screen.

4. The analysis should be rejected if the sum of the individual fractions is less than 98.0 grams or more than 102.0 grams.

5. Sample Calculations

Sieve No.	Wt. Retained on Sieve, gms	% Retained
8	6.4	6.4
12	17.5	17.6
16	23.5	23.7
20	48.0	48.3
Pan	3.9	3.9
Total =	99.3	

$$\% \text{ Retained} = \frac{\text{Weight Retained on Each Sieve}}{\text{Total Wt. Retained on all Sieves}} \times 100\%$$

L. Total Ash of Regenerated Carbon

The total ash of a carbon is a measure of the amount of the inorganic matter present. This test is accomplished by a combustion process in which organic matter is converted to carbon dioxide and water at a controlled temperature to prevent decomposition and volatilization of inorganic substances as much as is consistent with complete oxidation or organic matter.

1. Apparatus

Electric Furnace — Any types which can be controlled at 600 ± 25 degrees C.

Evaporating Dish — Shallow form, 80 mm diameter, 20 mm height.

Analytical Balance having a sensitivity of 0.1 mg.

Desiccator.

Oven, forced air circulation capable of temperature regulation between 100 and 150 degrees C.

2. Procedure

Heat an evaporating dish in an electrically heated furnace for thirty (30) minutes at 600 ± 25 degrees C, cool in a desiccator, and weigh. Weigh five (5) grams of the sample (dry weight basis) — dry at 110 degrees C for three (3) hours or 140 degrees C for one (1) hour into the tared dish, recording the exact weight of the dish and sample.

Ash the sample in the furnace at 600± 25 degrees C. The time required for complete ashing varies with the material being tested. Heating to constant weight assures complete ashing (leaving the sample in the furnace overnight will assure complete ashing). During ashing, the furnace door should be left slightly open to obtain an exchange of oxygen and gases. After ashing, cool the dish and sample in a desiccator and weigh.

3. Calculations

$$\text{Total Ash, \%} = \frac{(\text{Wt. dish and ash, g}) - (\text{Wt. dish, g})}{\text{Dry weight of sample, g}} \times 100\%$$

SUGGESTED ANSWERS

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Answers to questions on page 297.

6.0A Four of the general ways water is used by industries are:

1. As process water for industrial uses,
2. To make processing of other materials easier or more efficient,
3. To transport materials to, through, and from the industrial process, and
4. For cooling.

6.0B The three alternative arrangements possible for treating industrial wastewater are:

1. Discharge to a Publicly Owned Treatment Works (POTW) to be combined with municipal wastes and possibly wastes from other industries, treated, and returned to the environment.
2. Pre-treatment by industry, followed by discharge to a POTW, as above, and
3. Treatment by industry to the extent required before discharge to a receiving water.

Answers to questions on page 300.

6.0C Water can be biologically contaminated by bacteria, viruses and other microorganisms excreted from the human body and other warm-blooded animals. These excretions may reach the environment through (1) sanitary wastewater, (2) storm waters washing the land of animal wastes and (3) through certain industries, most notably slaughterhouses and tanneries.

6.0D Biologically contaminated water may be made safe by the *DISINFECTION* process.

6.0E The major potential sources of contamination of water by toxic materials is from the manufacturing processes in which these chemicals are either used or made and from in-plant spills and accidents.

6.0F Oxygen-consuming wastes provide food for aquatic microorganisms that remove dissolved oxygen from the water as they "breathe." Once all of the dissolved oxygen in the water is gone, the wastes are treated by anaerobic decomposition which produces unpleasant odors, colors and sludges that discourage water-contact recreation.

6.0G Toxicity may interfere with the following potential uses of water:

1. Drinking,
2. Cooking,
3. Water-contact recreation,
4. Fish, wildlife and aquatic vegetation,
5. Agricultural use, and
6. Industrial.

Answers to questions on page 302.

6.0H Dairy processing plants typically produce a waste very high in *BOD* and *SOLIDS*.

6.0I Flows from tannery wastes are highly variable because tanning is accomplished in a batch process.

6.0J Treatment of pulp and paper wastes is considered difficult because a lot of the raw material is rejected, a high volume of water is used in the process, organic loadings are relatively high and there is a natural resistance of the type of organic material in the wastes to biological oxidation. Treatment through biological oxidation, such as activated sludge, should be effective for this type of wastewater, however, it may be necessary to practice control of the pH level of the wastes as well as the nutrient level.

6.0K Economical by-products from packing house wastes include:

1. Glue,
2. Soap,
3. Animal feed, and
4. Fertilizer.

6.0L Fermentation is the breaking down of sugars and starches into simpler compounds by yeasts.

Answers to questions on page 305.

6.0M The two most significant problems encountered in the treatment of fruit and vegetable processing wastes are (1) the seasonal nature of the processing and (2) the nutrient deficiency commonly existing in the wastewater.

6.0N One advantage of anaerobic filters as applied to the processing of fruit and vegetable wastewater is that they can be used effectively on an intermittent basis.

6.0O Typical treatment problems in the textile industry include:

1. Lint, fibers and strings,
2. Natural greases,
3. Foam,
4. Highly alkaline and acidic wastes,
5. Fluctuations in flow, and
6. Toxic metals.

6.0P The principal problem of wastes from the petroleum industry is the brine.

6.0Q Five toxic substances found in metal finishing wastes include:

1. Acids,
2. Chromium,
3. Zinc,
4. Copper,
5. Nickel,
6. Tin, and
7. Cyanide.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 312.

6.1A Coagulants are used in the dissolved air flotation process to cause the formation of a large floc of solids, trapping the air bubbles inside. This can improve or increase the effectiveness of each single air bubble.

6.1B An operator must be able to identify the critical parts and their function because any incorrect identification or misuse could cause a decrease in performance of the system or total system shutdown.

6.1C The performance of a flotation unit feed pump could be adversely affected by improper operation, worn impellers, blockages or improper sizing.

6.1D The retention tank is a pressurized vessel where the mixing of the treated wastewater solution and air takes place. Without this tank, the flotation system would not operate.

6.1E The purpose of the flotation tank is to provide a location where the flocs are allowed to float to the surface and be removed by skimmers.

Answers to questions on page 314.

6.1F Failure to start the flight scraper drive immediately after the feed valve has been adjusted will allow the buildup of sludge to depths within the flotation compartment where shutdown and wash-up procedures will be necessary to clean out the unit.

6.1G If the flight scrapers travel too slowly, a heavy buildup of sludge will develop with the possibility of overloading the drive unit and plugging the flotation compartment.

6.1H If the flight scrapers travel too fast, too much disturbance will be created in the flotation compartment and the sludge will become diluted.

6.1I If the retention tank and flotation unit were not flushed out and washed down during the shutdown procedures, the performance level of the unit after start-up would be below accepted levels.

6.1J

Improper Procedure	**Consequence**
START-UP	
1. Not filling unit with fresh water before starting feed pump.	Damage to feed pump.
2. Not closing drain valve before filling unit.	Waste of water and time.
3. Not turning on air.	Effluent quality will suffer.
SHUTDOWN	
1. Leaving chemicals on until after job's completed.	Waste of chemicals and money.
2. Opening and closing drain valve on the retention tank after the feed pump was shut off.	Waste of energy.

6.1K Waste stream evaluation is very critical to the solving of problems, for the prevention of problems, and as an aid in troubleshooting the flotation system.

6.1L

Serious Indicator	**Cause**
1. Variation of flow.	Blockage in the feed-pump or the pump has been worn out.
2. Variation in odors.	Normal system wash-up schedule has not been followed.

Answers to questions on page 316.

6.1M A daily operation log is necessary for accurate recording of system data, system evaluation, and meeting discharge permit requirements.

6.1N Information that can be obtained from analysis of the accumulated log data includes:

1. General trends such as gradual system slime buildups,
2. Seasonal variations,
3. Results of overloadings or slugs,
4. Information to operate the system,
5. Information to operate new systems,
6. Base data for discharge permit modifications, and
7. Indications of operators needing additional training.

6.1O The two types of sampling are for:

1. Discharge permit compliance, and
2. Operation log book.
   Grab and composite are also two types of sampling.

6.1P Basic rules to follow when correcting a problem include:

1. Assess the problem,
2. List possible corrective actions,
3. Proceed to correct the problem by doing one corrective action (or change one variable) at a time,
4. Record all actions,
5. Evaluate system response to each action, and
6. After problem is corrected, try to prevent it from developing again.

6.1Q Wait long enough between changes for each change to take effect and to observe the effectiveness of the change in correcting the problem.

6.1R Continuous monitoring is required when abnormal indicators are present.

Answers to questions on page 318.

6.1S Preventive maintenance is that maintenance which is performed on equipment to keep it from malfunctioning.

6.1T Preventive maintenance procedures done too often are a waste of time and energy, and could possibly lead to component or part damage. If procedures are done at irregular time intervals or not at all, part failure or other problems could develop.

6.1U All part settings should be returned to original settings so the operator knows where the system is operating. The replacement of guards is required so nobody will take for granted that the guards are in place, when they are not, and possibly get seriously injured.

6.1V The four major areas of plant operation that are influenced by preventive maintenance are:

1. Overall system operation,
2. System performance levels,
3. Budget, and
4. Receiving water quality.

Answers to questions on page 319.

6.1W Corrective maintenance is the repair or replacement of malfunctioning components. This type of maintenance usually requires the total shutdown of the system.

6.1X The causes of part malfunction include:

1. Lack of proper preventive maintenance,
2. Improper installation,
3. Product defects,
4. Improper operation,
5. Old age, and
6. Overloading.

6.1Y A spare parts inventory is a necessity. Without the inventory unnecessary down-time of the system will be adding up and will drastically affect the discharge stream or solids and water recovery.

6.1Z Quick and efficient corrective maintenance is required to get the job done as quickly as possible before adverse conditions arise because of system down-time.

END OF QUESTIONS IN LESSON 2

Answers to questions on page 321

6.2A The purpose of screens and microscreens is to intercept and remove suspended solids from the flowing wastewater.

6.2B Microscreens could be an aid to disinfection by removing floatable and suspended solids prior to the disinfection process.

Answers to questions on page 330.

6.2C Different types of screens may be listed as

1. Coarse screens
   Intermediate grade of medium screening
   Microscreens
2. Stationary screens
   Moving screens
   Microscreens

6.2D The following types of controls can be used alone or in combination to clean screens:

1. Manual start/stop,
2. Automatic start/stop by time control,
3. High level switch, and
4. Differential head switch.

6.2E Clean water used to backwash screens and filter media must be low *OR WITHOUT SUSPENDED SOLIDS.*

6.2F The speed of a variable-speed moving screen can be controlled on the basis of the upstream channel level, flow level, or head differential through the screen.

Answers to questions on page 331.

6.2G An insufficient oxygen problem can be corrected by ventilation using fans and/or blowers.

6.2H Before working in an area open to traffic:

1. Put up barriers and signs,
2. Turn on rotating beacon on trucks, and
3. Wear a hard hat and a red vest.

Answers to questions on page 332.

6.2I During start-up check to see if debris and solids are being flushed off the screen and are running to disposal.

6.2J Major items that should be checked during the normal operation of a microscreen include:

1. Screening media,
2. Cleaning system,
3. Drive unit and other moving machinery,
4. Effectiveness of seals and gaskets,
5. Strength and stability of supporting framework,
6. Drum speed,
7. Screen submergence, and
8. Head loss.

6.2K Heavy plugging of a screen could be caused by

1. High solids loads, and/or
2. A defective cleaning system.

6.2L Correct shutdown procedures have been used if the screen or microscreen is in a clean condition when the chambers are dry and empty.

Answers to questions on page 337.

6.2M Items that should be visually inspected every day a screen is in operation include:

1. Condition of screening media,
2. Objects lodged in screen or obstructing flow or equipment movement,
3. Vibrating or erratically moving equipment,
4. Wash water jet nozzles for blockage, and
5. Head loss.

6.2N A woven wire cloth can be broken by impingement of floating objects or by stress due to overloading from differential head and fatigue.

Answers to questions on page 339.

6.2O When reviewing plans and specifications regarding concrete channels and chambers, check

1. Provisions for drainage of facilities,
2. To be sure dirty water is prevented from bypassing the screen,
3. That chlorine is prevented from reaching the unit or backwash pump,
4. That adequate working space is provided for operation and maintenance, and
5. Provisions for guard rails and other safety requirements.

6.2P When reviewing plans and specifications regarding electrical outlets, check for

1. Location near points of need, and
2. Proper voltage.

END OF ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 348.

6.3A The lower the pH, the greater the rate of corrosion. If the pH of a solution is allowed to drift outside of the design range, corrosion can start.

6.3B pH is an index of hydrogen ion activity and is used as an indication of acidity and alkalinity while not a measure of either.

6.3C Alkalinity is the capacity of water or wastewater to neutralize acids. It is the sum total of components in the water that tend to elevate the pH of the water above a value of about 4.5. Alkalinity is a measure of the buffering capacity of the water and may be defined as its capacity for neutralizing acid.

6.3D To treat the same water, lime will produce more sludge than caustic soda.

6.3E When diluting caustic soda, consideration must be given to heat generated. The rate of dilution and method of cooling must be carefully controlled so that there is no boiling or splattering.

6.3F A titration curve is a plot of pH versus titrant added to a solution. The curve provides a means of characterizing the substance to be pH adjusted or neutralized and the amount of adjusting agent required.

Answers to questions on page 357.

6.3G Treatment processes that may require pH adjustment and neutralization include:

1. Precipitation of metal salts,
2. Coagulation and flocculation,
3. Biological processes,
4. Reverse osmosis,
5. Ozonization,
6. Carbon adsorption,
7. Ultrafiltration,
8. Sludge conditioning and disposal,
9. Phosphorus removal, and
10. Effluent disposal.

6.3H The most commonly used coagulants are:

1. Alum or aluminum sulfate — $Al_2(SO_4)_3$,
2. Ferric chloride — $FeCl_3$, and
3. Ferric sulfate — $Fe_2(SO_4)_3$.

6.3I Ultrafiltration is a membrane filtration process used for the removal of organic compounds in an aqueous (watery) solution.

6.3J Sludges are often classified by their basic chemical composition, pH, specific resistance and cake solids.

Answers to questions on page 363.

6.3K In a batch process the waste is collected in a tank, pH is adjusted and then the waste is allowed to re-enter the wastewater stream.

6.3L pH can be determined manually by using electrometric measurement (a lab pH meter) and special indicator paper (litmus or pHydrion paper).

6.3M Ventilation should be provided in chemical feed facilities to minimize chemical exposure to personnel, controls and equipment.

6.3N An alert operator should be able to walk into a room under construction and consider the following questions:

1. Can I service and maintain the equipment safely?
2. Are switches and controls adequate and properly located?
3. Is lighting sufficient?
4. Is ventilation sufficient?
5. Is proper entrance and exit from the room provided?
6. Are emergency alarms provided?

6.3O Formal procedures should be developed for start-up, operation and shutdown of equipment and processes to define areas of responsibility and to significantly reduce the chances of errors and accidents.

END OF ANSWERS TO QUESTIONS IN LESSON 4

Answers to questions on page 368.

6.4A Chemical coagulation involves the operations of rapid mix, flocculation and clarification.

6.4B Coagulation is the actual gathering together of smaller suspended particles into flocs, thus forming a more readily settleable mass.

6.4C Flocculation is the act of mixing and stirring the particles so as to insure adequate contact between suspended particles and the coagulating chemical.

6.4D If the rapid mix is too long, the forming floc may be broken up and become separated.

6.4E Polymers are considered more convenient in the liquid form because they may be used directly, thus eliminating the need to make up working solutions.

Answers to questions on page 383.

6.4F Rapid mixing of coagulant chemicals may be accomplished in one of three modes: (1) high-speed mixers (impeller or turbine), (2) in-line blenders and pumps, and (3) baffled compartments or pipes (static mixers).

6.4G In tapered flocculation, a small dense floc is formed initially followed by aggregation to form a more dense dispersed floc.

6.4H An advantage of vertical-flow clarifier units is that flow is forced up through a sludge blanket, thus aiding in solids retention and improving flow control.

6.4I Four factors that are considered in the design of clarifiers include:

1. Detention time,
2. Weir overflow rate,
3. Surface loading rate, and
4. Solids loading.

OR

1. Flows,
2. Suspended solids,
3. Settleable solids, and
4. Floatable solids.

6.4J If the detention time in a clarifier is too short, there will be a carryover of particles into the effluent.

6.4K Short-circuiting may be caused by:

1. Differences in water density due to different temperatures existing at the surface and bottom of the clarifier;
2. Density differences due to suspended solids;
3. High inlet and outlet velocities; and
4. Strong winds blowing along the surface of the tank.

Answers to questions on page 386.

6.4L Gases under pressure should be stored in a cool location and secured tightly to a vertical support. Areas should be properly labeled to designate hazard of flammability, corrosiveness or other applicable type of hazard.

6.4M Some of the causes of falls include clutter and grease, oil and polymer spills.

6.4N Items to be checked during the start-up inspection of a chemical feed system include:

1. Level alarms in tanks,
2. Calibration of flow and metering systems,
3. Water blenders and dilution mixers,
4. Temperature and pressure of dilution water, and
5. In-line mixers.

6.4O Procedures for the normal operation of a chemical coagulation-precipitation system include:

1. Perform a jar test to determine the proper chemical dosage,
2. Insure proper chemical dilution,
3. Set controls for proper feed rate, and
4. Report in the operating log the amount of chemicals used per unit time.

END OF ANSWERS TO QUESTIONS IN LESSON 5

Answers to questions on page 387.

6.5A The activated carbon adsorption process is used to treat wastewater to remove organic pollutants from the plant's effluent. Color-, taste- and odor-causing pollutants are removed by the activated carbon adsorption process.

6.5B Activated carbon may be made from wood, coal, nutshells, bone, petroleum residues or sawdust.

6.5C Carbon is made by drying the raw material and slowly heating the material in the absence of air.

Answers to questions on page 401.

6.5D The desired detention time in an activated carbon pressure vessel is 30 minutes.

6.5E Three-way valves are used in activated carbon piping to provide both the upflow conditions necessary for the activated carbon treatment, and also to allow for backwashing of filter screens.

6.5F Activated carbon is kept in the pressure vessel by screens located at both the top and bottom of the vessel.

6.5G The counter-current flow principle is the process where flow enters the bottom of the carbon column and new or regenerated carbon is added to the top of the container. This principle allows for the oldest carbon to contact the wastewater first and the newest or more virgin carbon to make contact with the effluent last. In this manner, the wastewater is polished as it flows up through the carbon column.

Answers to questions on page 406.

6.5H Regeneration of activated carbon is a process whereby the pores and the surface of the carbon are cleansed of the molecular organic material which has been adsorbed on the surface.

6.5I If the feed rate is too high to the carbon regeneration furnace, the carbon does not have a long enough detention time within the furnace to be regenerated properly.

6.5J If the feed rate is too low to the carbon regeneration furnace, the carbon will be burned in the furnace and lose its effectiveness.

6.5K The temperature in a carbon regeneration furnace is controlled by adjusting the air and gas ratio.

6.5L The purpose of the defining tank for the activated carbon is to wash the carbon as thoroughly as possible to prevent the small particles of carbon from causing further problems within the adsorption process. An adequate amount of time must be given to the defining process to be certain that as many of the fine particles are removed as possible.

Answers to questions on page 409.

6.5M Possible causes of high head losses through an activated carbon process include:

1. Need for backflushing,
2. Fouling of activated carbon granules with suspended solids,
3. Screen plugged or collapsed, and
4. Amount of carbon in the adsorption reactor is too high.

6.5N The activated carbon column reactor should be filled slowly to prevent air pockets from forming in the reactor and causing short-circuiting.

6.5O If a wastewater treatment process upstream from a carbon adsorption process failed, try to prevent suspended solids from reaching the carbon adsorption process. If an emergency holding pond is available, temporarily store the inadequately treated wastewater until the upstream process is working again.

6.5P Problems that could be encountered when operating a carbon regeneration furnace include:

1. Deterioration of refractory brick,
2. Improper air and gas mixture,
3. Worn out furnace rabble arms,
4. Excessively worn regenerated carbon slurry pumps, and
5. Plugged screens in the make-up carbon or regenerated carbon defining tank.

Answers to questions on page 411.

6.5Q Activated carbon could cause an oxygen deficiency in a carbon column reactor vessel because activated carbon adsorbs oxygen molecules.

6.5R Items that should be considered when reviewing plans and specifications for an activated carbon adsorption process include:

1. Loading station for delivery of fresh activated carbon,
2. Location of valves within easy reach,
3. Dust control for unloading fresh carbon,
4. Proper ventilation in carbon regeneration furnace room,
5. Scaffolding and catwalks,
6. Warning alarms and signs, and
7. Upstream processes.

6.5S Alarms should be provided to notify personnel of excessive temperatures or lack of oxygen within a building. Signs should warn personnel of dangers associated with working around activated carbon.

END OF ANSWERS TO QUESTIONS
IN LESSON 6

OBJECTIVE TEST

Chapter 6. INDUSTRIAL WASTE TREATMENT PROCESSES

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one answer to each question.

1. Regardless of the source, water used by industry may require additional treatment before it is suitable for use.
   1. True
   2. False
2. The health risks from water-contact recreation are greater than from drinking water.
   1. True
   2. False
3. Air cooling is an effective alternative to water cooling in the fruit and vegetable processing industry.
   1. True
   2. False
4. The frequency of monitoring should increase when abnormal indicators are present.
   1. True
   2. False
5. Corrective maintenance frequently requires total shutdown of the system to perform the necessary procedures.
   1. True
   2. False
6. Some bar screens have horizontal bars instead of vertical bars.
   1. True
   2. False
7. The only cleaning mechanism for some bar screens is the force of the water which sweeps the intercepted material off the face of the screen. Manual cleaning by brushing or hosing is required periodically.
   1. True
   2. False
8. pH is an important factor in the chemical and biological systems of natural waters.
   1. True
   2. False
9. pH is considered to be the single most important variable in the coagulation process.
   1. True
   2. False
10. At low pH values, ultrafiltration membrane technology is most appropriate.
    1. True
    2. False
11. Industrial wastewater flows and strength of contaminants are usually constant during each shift.
    1. True
    2. False
12. Dry alum is corrosive unless it absorbs moisture.
    1. True
    2. False
13. The settling rate of particles is greater at a warmer temperature than it is at a lower temperature.
    1. True
    2. False
14. The carbon adsorption process uses an upflow pressure vessel in order to allow adequate detention time within the vessel for adsorption of the organic material in the effluent waters.
    1. True
    2. False
15. Activated carbon column reactors are lined with an epoxy or resin because wet carbon can be very corrosive.
    1. True
    2. False
16. Carbon dust should not be inhaled.
    1. True
    2. False

17-21. The following is a list of common household items. If the item is *ACIDIC*, mark *1* for the correct answer and mark *2* if the answer is *BASIC*.

	1. *ACIDIC*	2. *BASIC*
17. Beer	________	________
18. Borax	________	________
19. Milk	________	________
20. Orange juice	________	________
21. Milk of magnesia	________	________

22. Which of the following uses of water has the highest priority of use?
    1. Agricultural
    2. Drinking
    3. Fish
    4. Industrial
    5. Water-contact recreation
23. Water-contact recreation includes
    1. Fishing.
    2. Picnicking.
    3. Sailing.
    4. Swimming.
    5. Water skiing.

24. Tannery wastes are usually high in
    1. BOD.
    2. Coliforms.
    3. Suspended solids.
    4. Salt.
    5. Temperature.

25. The basic purposes of the flotation process are
    1. Biological treatment.
    2. Grit removal.
    3. Solids recovery.
    4. Water recovery.
    5. Wastewater treatment.

26. Potential safety hazards within a flotation system include
    1. Chemical handling.
    2. Couplings.
    3. Electrical systems.
    4. Sprockets.
    5. Wet floors.

27. Incorrect flotation start-up procedures or steps taken out of sequence can be detected by
    1. High solids content of solids recovery.
    2. No chlorine residual in effluent.
    3. Observing indicator lights.
    4. Poor effluent quality.
    5. Visual appearance of unit.

28. Frequency of normal system monitoring should be
    1. As often as possible.
    2. Each shift monitors itself.
    3. Every hour.
    4. Once a day.
    5. Once a week.

29. Pertinent procedures in flotation system preventive maintenance include
    1. Adjusting scraper alignment.
    2. Cleaning system.
    3. Installing new unit feed pump.
    4. Painting facilities.
    5. Replacing broken belt.

30. Lack of proper preventive maintenance can be revealed by
    1. Continuous uneven part wear.
    2. Dirty equipment.
    3. Insufficient oil or grease.
    4. Old age of components.
    5. Overloading.

31. Microscreens are used mainly for final treatment to (select best answer)
    1. Filter out phosphorous in the effluent.
    2. Prevent nutrients in the effluent from reaching the receiving waters.
    3. Prevent the carryover of floating solids and suspended particles remaining in effluent.
    4. Remove microorganisms remaining in effluent.
    5. Remove pathogenic organisms remaining in effluent.

32. The fabric of a microscreen may be made of
    1. Cloth.
    2. Nylon.
    3. Polyester.
    4. Stainless steel.
    5. Teflon.

33. Hazardous fumes, gases or conditions that might be encountered in a confined space include
    1. Gasoline vapors.
    2. Hydrogen sulfide.
    3. Lack of oxygen.
    4. Solvent fumes.
    5. Toxic gases.

34. Safety equipment or tools include
    1. Atmospheric or gas measuring instruments.
    2. Gas mask (hose type or air breathing apparatus).
    3. Rubber gloves.
    4. Safety belt and harness.
    5. Spark-proof tools.

35. Sampling of wastewater being treated by a screening process should
    1. Be either by grab samples or continuous monitoring.
    2. Have all samples chlorinated.
    3. Have samples collected before and after the screening media.
    4. Have the samples analyzed at the point of collection.
    5. Require all collected samples to be filtered before analysis.

36. Problems operating a screen properly could be caused by
    1. Erratic movement of equipment parts.
    2. High grease solids.
    3. High solids loads.
    4. Openings in the screen being too large.
    5. Overloading of upstream treatment processes.

37. Acids commonly used in lowering the pH of a solution include
    1. Acetic acid.
    2. Hydrochloric acid.
    3. Nitric acid.
    4. Phosphoric acid.
    5. Sulfuric acid.

38. Efficiency of the ultrafiltration membrane filtration process can be measured in terms of
    1. Cake filterability.
    2. Clarity of the solute.
    3. Dissolved solids rejected.
    4. Horsepower in and out.
    5. Organic matter rejected.

39. Different types of coagulating chemicals include
    1. Anionic precipitators.
    2. Electrostatic charge reducing.
    3. Flocculating.
    4. Interparticle bridgers.
    5. Physical enmeshers.

40. Iron compounds used as coagulants are
    1. A potential source of iron in the effluent.
    2. Capable of increasing the BOD in the effluent.
    3. Corrosive.
    4. Difficult to dissolve in water.
    5. Potentially dangerous if they (ferric sulfate or copperas) come in contact with quicklime.

41. What could be the possible causes of the floc being too small in a chemical coagulation and flocculation system?
    1. Change in pH
    2. Chemical feed pump adjusted too low
    3. Improper chemical dosage
    4. Paddle speed in flocculators too fast
    5. Short-circuiting

42. What could be the cause of excessive carbon fines in the effluent from activated carbon column reactors?
    1. Carbon is being produced in the reactor due to poor combustion
    2. Carbon is flowing out in the effluent due to a hole in one of the screens
    3. Carbon is rubbing too drastically against the screens
    4. Microscreens are breaking up the carbon floc upstream from the reactor
    5. Pin floc containing carbon is escaping from the secondary clarifier

43. Daily operational procedures for an activated carbon process include
    1. Backflushing of fine-mesh screens.
    2. Measuring BOD removal efficiencies.
    3. Measuring COD removal efficiencies.
    4. Measuring effluent turbidity.
    5. Measuring level of carbon remaining in reactor.

44. When operating an activated carbon adsorption process, which of the following items should be checked once each shift?
    1. Dissolved oxygen level in each carbon adsorption unit
    2. Head loss through each carbon adsorption unit
    3. Position of all valves to and from each carbon adsorption unit
    4. Rate of flow to each carbon adsorption unit
    5. Sample influent and effluent of each carbon adsorption unit

45. Loading rates for activated carbon adsorption processes include
    1. Chemical oxygen demand.
    2. Hydraulic.
    3. Organic.
    4. Overflow.
    5. Surface.

END OF OBJECTIVE TEST!

CHAPTER 7

MAINTENANCE

by

Roger Ham

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Chapter 7. Maintenance

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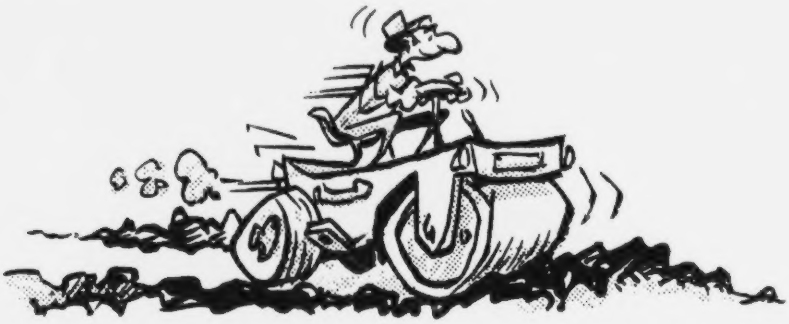
OBJECTIVES

Chapter 7. MAINTENANCE

Following completion of Chapter 7 you should be able to do the following:

1. Select, operate and maintain portable pumps, pipes, valves, and fittings used for maintenance and repair jobs;
2. Safely operate and maintain auxiliary electrical equipment, including during standby and emergency situations;
3. Start up, operate, maintain and shut down gasoline engines, diesel engines, heating, ventilating and air conditioning systems;
4. Operate and maintain the plant air and water systems; and
5. Maintain the treatment plant grounds, including drainage water system, yard lighting, paving, walkways and landscaping.



GLOSSARY

Chapter 7. MAINTENANCE

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the drinking water.

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.

CAVITATION (CAV-i-TAY-shun) CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.

CROSS CONNECTION CROSS CONNECTION

A connection between drinking (potable) water and an unsafe water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

DISCHARGE HEAD DISCHARGE HEAD

The pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the discharge side of a pump. The pressure can be measured from the center line of the pump to the hydraulic grade line of the water in the discharge pipe.

DYNAMIC HEAD DYNAMIC HEAD

When a pump is operating, the vertical distance (in feet or meters) from a point to the energy grade lines. Also see TOTAL DYNAMIC HEAD and STATIC HEAD.

ELECTRO-CHEMICAL CORROSION ELECTRO-CHEMICAL CORROSION

The decomposition of a material by: (1) stray current electrolysis, (2) galvanic corrosion caused by dissimilar metals, and (3) galvanic corrosion caused by differential electrolysis.

ELECTRO-CHEMICAL PROCESS ELECTRO-CHEMICAL PROCESS

A process that causes the deposition or formation of a seal or coating of a chemical element or compound by the use of electricity.

ELECTROLYSIS (ELECT-TROLLY-sis) ELECTROYLSIS

The decomposition of material by an electrical current.

ELECTROLYTE (ELECT-tro-LIGHT) ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

ENERGY GRADE LINE (EGL) ENERGY GRADE LINE (EGL)

A line that represents the elevation of energy head (in feet) of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel.

FRICTION LOSS FRICTION LOSS

The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.

HEAD HEAD

A term used to describe the height or energy of water above a point. A head of water may be measured in either height (feet or meters) or pressure (pounds per square inch or kilograms per square centimeter). Also see DISCHARGE HEAD, DYNAMIC HEAD, STATIC HEAD, SUCTION HEAD, SUCTION LIFT, and VELOCITY HEAD.

HYDRAULIC GRADE LINE (HGL) HYDRAULIC GRADE LINE (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. To reduce the release of odors from wastewater, the water surface should be kept as smooth as possible.

OXIDATION (ox-i-DAY-shun) OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. The opposite of REDUCTION.

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. The opposite of OXIDATION.

SEIZE UP SEIZE UP

Seize up occurs when an engine overheats and a component expands to the point where the engine will not run. Also called "freezing."

STATIC HEAD STATIC HEAD

When water is not moving, the vertical distance (in feet or meters) from a point to the water surface.

SUCTION HEAD SUCTION HEAD

The *POSITIVE* pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the suction side of a pump. The pressure can be measured from the center line of the pump *UP TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUCTION LIFT SUCTION LIFT

The *NEGATIVE* pressure (in feet (meters) or inches (centimeters) of mercury vacuum)) on the suction side of the pump. The pressure can be measured from the center line of the pump *DOWN TO* the elevation of the hydraulic grade line on the suction side of the pump.

TOTAL DYNAMIC HEAD (TDH) TOTAL DYNAMIC HEAD (TDH)

When a pump is lifting or pumping water, the vertical distance (in feet or meters) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

VELOCITY HEAD VELOCITY HEAD

A vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

WATER HAMMER WATER HAMMER

The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.

CHAPTER 7. MAINTENANCE

(Lesson 1 of 4 Lessons)

7.0 IMPORTANCE OF MAINTENANCE

Maintenance of equipment (support systems) helps treatment plants perform their intended purpose of treating wastewater. If the equipment at your treatment plant is properly operated and maintained, you can concentrate your efforts on the actual treatment of wastewater and the quality of your plant's effluent.

Equipment includes portable pumps, pipes, valves and fittings that are used to help you operate and maintain your treatment plant. Other support system facilities include auxiliary electrical equipment, gasoline engines, diesel engines, heating, ventilating and air conditioning. Two very important support systems are the plant air and water systems. The air system includes instrument air, chemical air padding, cleaning, and shop blowdown. Plant water systems must be carefully installed and inspected to protect potable (drinking) water from nonpotable water used for foam control, wash down and irrigation. Many people determine how effectively you are doing your job by the appearance of your plant. For this reason you should be able to control drainage runoff, maintain a well-lighted plant, keep walkways and roadways clear and free of holes and bumps and present a nice appearing and landscaped treatment plant. All of these factors must be the concern of treatment plant operators. When support systems perform properly, operator morale is improved as well as plant performance.

7.1 PORTABLE PUMPS

The use of portable pumps is widespread in the wastewater treatment field. Pumps vary in design to meet the particular needs of the user or the job to be done. Within this field you may be required to move water containing grit, other solids, groundwater, and wastewater to name a few different types of water and solids that must be pumped. Before selecting a pump, thought must be given to the following factors:

1. Type of liquid and solids,
2. Distance liquid is to be pumped,
3. Pressure liquid is to be delivered,
4. Pumping rate in gallons per minute, and
5. Type of power needed (gasoline or diesel engine, electric motor, or pneumatic).

If you are contemplating the purchase of a new pump, list all the operating factors and the type of power best suited for your situation. Don't forget that price is also an important factor. There is no need to buy an expensive pump if one of lesser quality and price will fulfill your needs. Also be sure to consider energy, operating and maintenance costs. Because of the substantial investment involved, consider if each pump studied will do the job, do it economically, have few operational problems, require spare parts that are readily available, and also if the company selling the pump is service oriented.

In order to select the proper pump, you must be familiar with the terms in the following paragraphs that are associated with pumps. Figures 7.1 and 7.2 illustrate these terms.

DISCHARGE HEAD

The pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the discharge side of a pump. The pressure can be measured from the center line of the pump to the hydraulic grade line of the water in the discharge pipe.

DYNAMIC HEAD

When a pump is operating, the vertical distance (in feet or meters) from a point to the energy grade lines. Also see TOTAL DYNAMIC HEAD and STATIC HEAD.

ENERGY GRADE LINE (EGL)

An imaginary line that represents the elevation of energy head (in feet) of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line, a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel. This line represents the total energy of water flowing in a pipe or channel.

FRICTION LOSS

The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.

HEAD

A term used to describe the height or energy of water above a point. A head of water may be measured in either height (feet or meters) or pressure (pounds per square inch or kilograms per square centimeter). Also see DISCHARGE HEAD, DYNAMIC HEAD, STATIC HEAD, SUCTION HEAD, SUCTION LIFT, and VELOCITY HEAD.

HYDRAULIC GRADE LINE (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. To reduce the release of odors from wastewater, the water surface should be kept as smooth as possible.

STATIC HEAD

When water is not moving, the vertical distance (in feet or meters) from a point to the water surface.

SUCTION HEAD

The *POSITIVE* pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the suction

NOTE: This figure illustrates a pump with a suction *LIFT*. Pumps should have a positive suction *HEAD* which means the wet well water level should be higher than the pump impeller. This pump will have difficulty starting unless it is a self-priming pump because the water level in the wet well is below the pump. Also, if air gets into the suction line, the only way it can get out is through the pump.

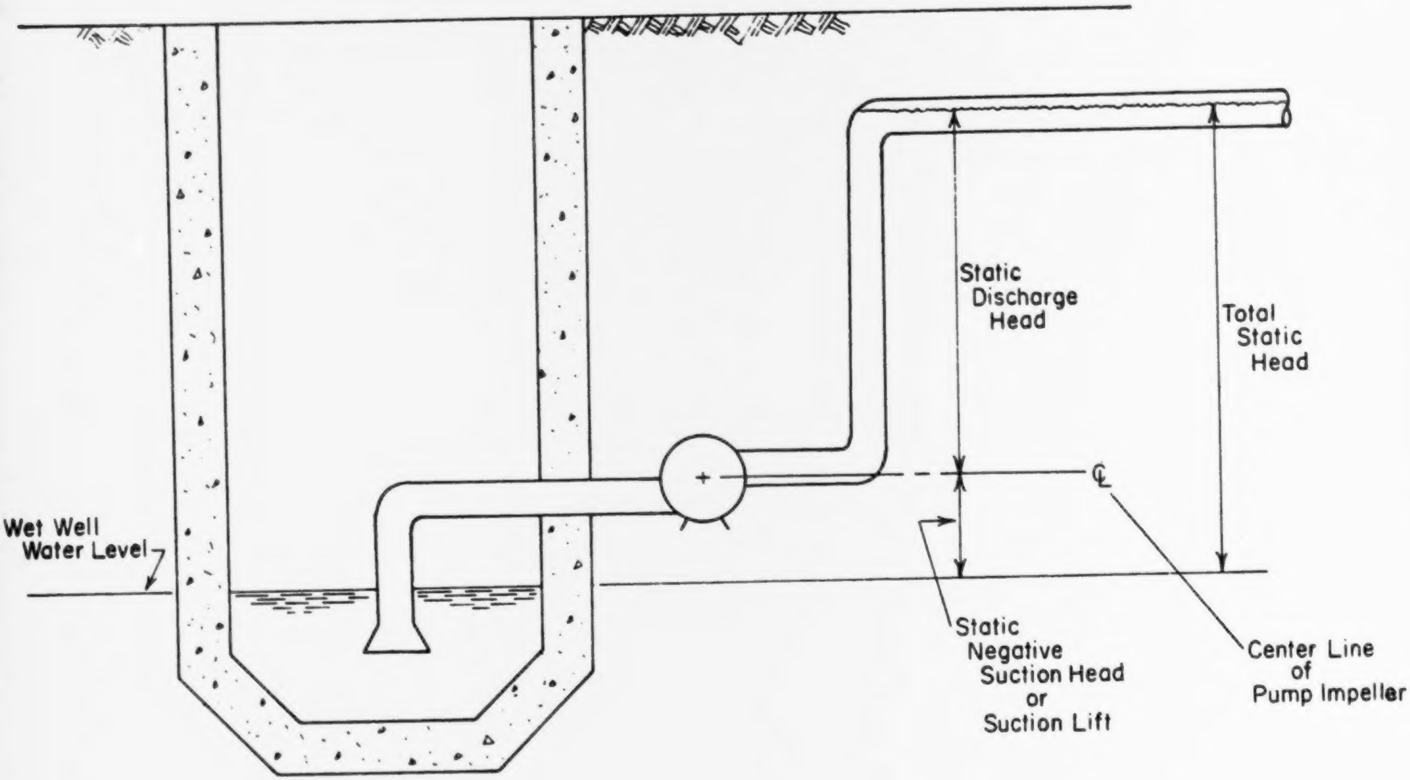

Static Discharge Head
Total Static Head
Wet Well Water Level
℄
Static Negative Suction Head or Suction Lift
Center Line of Pump Impeller

Fig. 7.1 Static heads (pump is not operating)

(from Operation and Maintenance of Wastewater Collection Systems)

NOTE: This figure illustrates a pump with a suction *LIFT*. Pumps should have a positive suction *HEAD* which means the wet well water level should be higher than the pump impeller. This pump will have difficulty starting unless it is a self-priming pump because the water level in the wet well is below the pump. Also, if air gets into the suction line, the only way it can get out is through the pump.

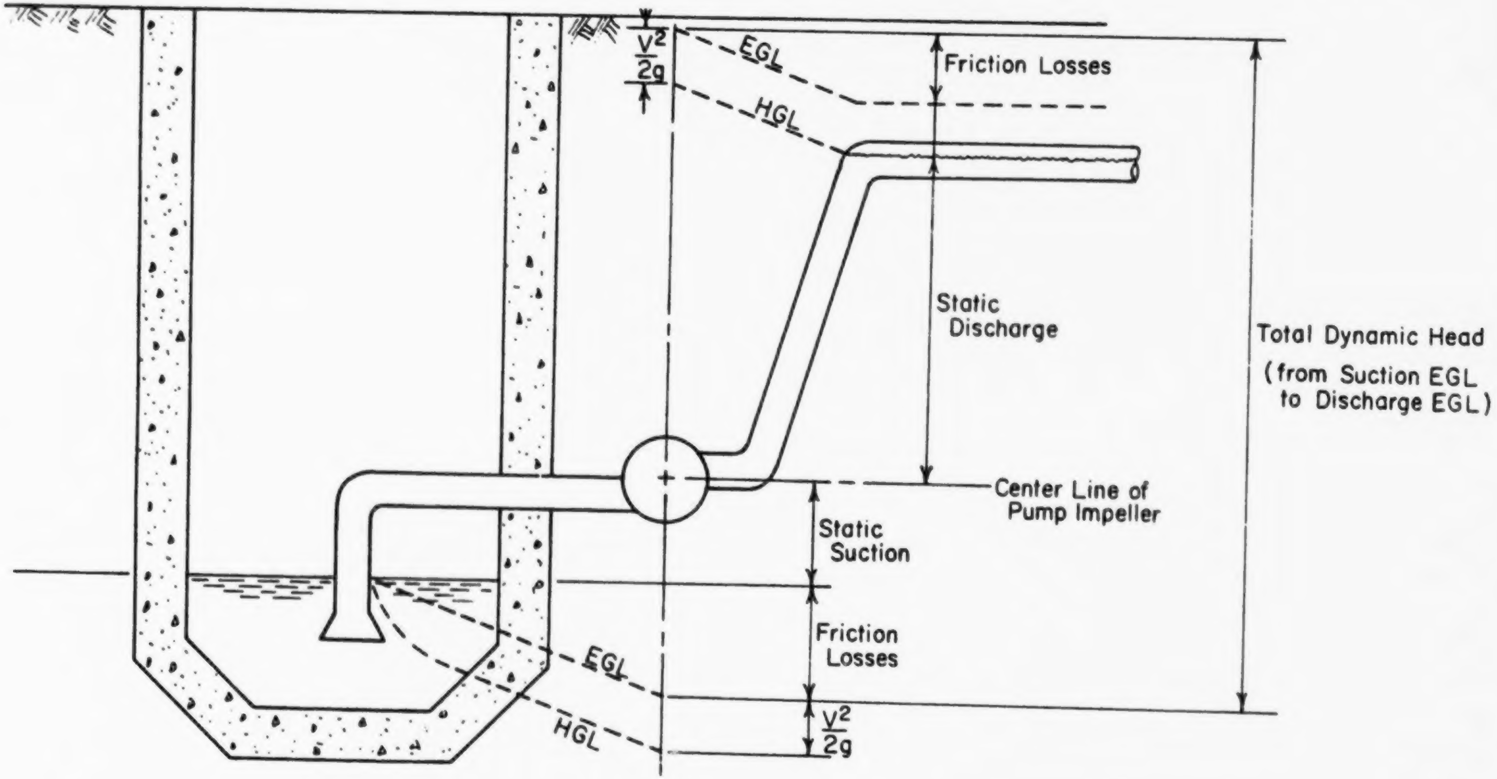
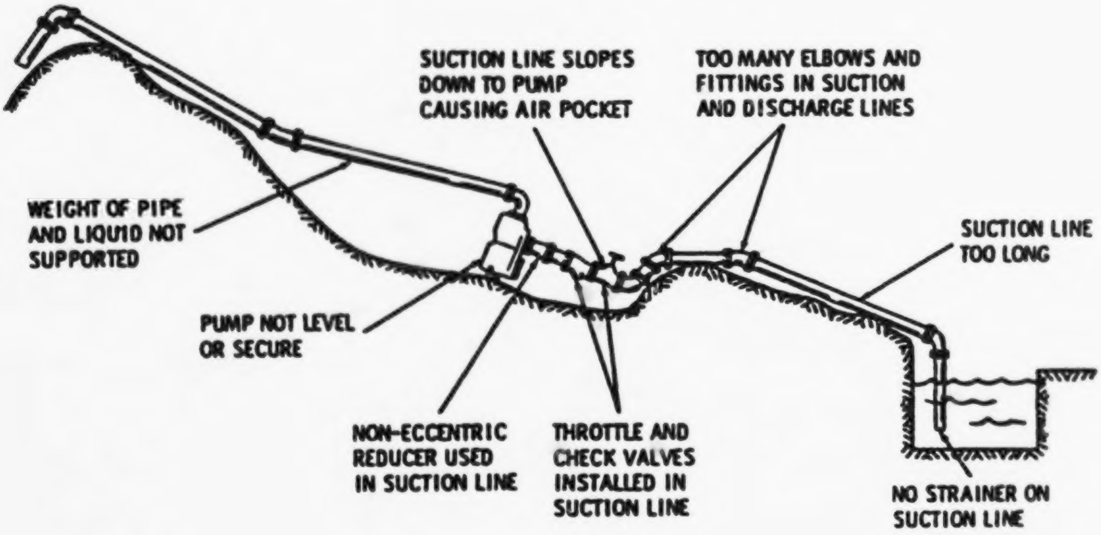

$\frac{V^2}{2g}$
EGL
HGL
Friction Losses
Static Discharge
Total Dynamic Head (from Suction EGL to Discharge EGL)
Center Line of Pump Impeller
Static Suction
Friction Losses
EGL
HGL
$\frac{V^2}{2g}$

Fig. 7.2 Dynamic heads (pump is operating)
(from Operation and Maintenance of Wastewater Collection Systems)

EGL - Energy Grade Line
HGL - Hydraulic Grade Line
$\frac{V^2}{2g}$ - Velocity Head

A IMPROPER PUMP INSTALLATION


SUCTION LINE SLOPES DOWN TO PUMP CAUSING AIR POCKET
TOO MANY ELBOWS AND FITTINGS IN SUCTION AND DISCHARGE LINES
WEIGHT OF PIPE AND LIQUID NOT SUPPORTED
SUCTION LINE TOO LONG
PUMP NOT LEVEL OR SECURE
NON-ECCENTRIC REDUCER USED IN SUCTION LINE
THROTTLE AND CHECK VALVES INSTALLED IN SUCTION LINE
NO STRAINER ON SUCTION LINE

B PROPER PUMP INSTALLATION

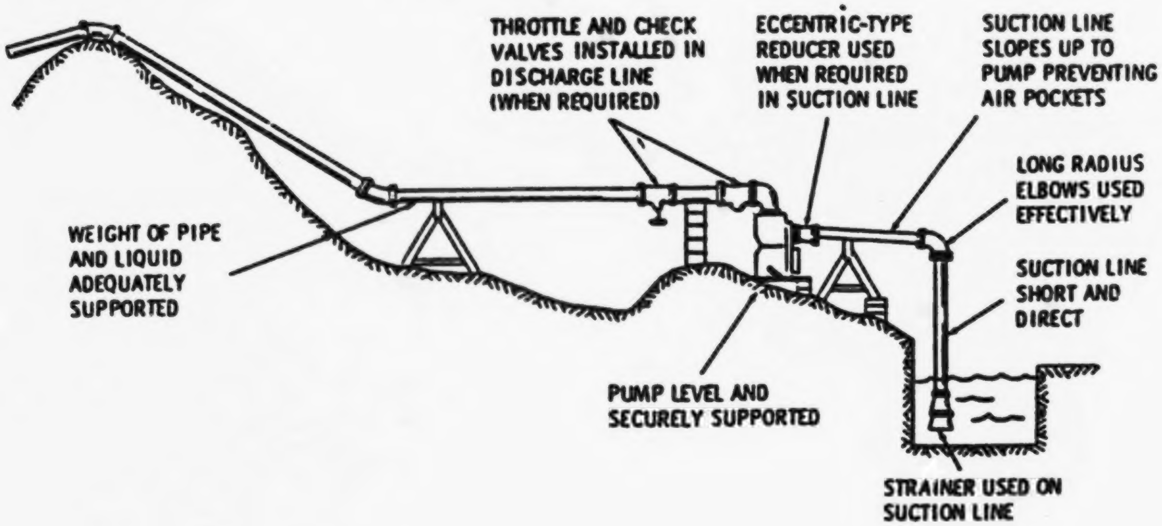

THROTTLE AND CHECK VALVES INSTALLED IN DISCHARGE LINE (WHEN REQUIRED)
ECCENTRIC-TYPE REDUCER USED WHEN REQUIRED IN SUCTION LINE
SUCTION LINE SLOPES UP TO PUMP PREVENTING AIR POCKETS
LONG RADIUS ELBOWS USED EFFECTIVELY
WEIGHT OF PIPE AND LIQUID ADEQUATELY SUPPORTED
SUCTION LINE SHORT AND DIRECT
PUMP LEVEL AND SECURELY SUPPORTED
STRAINER USED ON SUCTION LINE

Fig. 7.3 Examples of proper and improper portable pump installations

(Permission of the Gorman-Rupp Company, Mansfield, Ohio) side of a pump. The pressure can be measured from the center line of the pump *UP TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUCTION LIFT

The *NEGATIVE* pressure (in feet (meters) or inches (centimeters) of mercury vacuum) on the suction side of the pump. The pressure can be measured from the center line of the pump *DOWN TO* the elevation of the hydraulic grade line on the suction side of the pump.

TOTAL DYNAMIC HEAD (TDH)

When a pump is lifting or pumping water, the vertical distance (in feet or meters) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

VELOCITY HEAD

A vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

Figure 7.3 shows examples of proper and improper portable pump installations. When using portable pumps to dewater tanks or ditches for repairs or maintenance, the items noted in this figure must be considered. Figure 7.4 shows proper and improper suction lifts for portable pumps. Always try to have the suction lift as low as possible and the suction line as short as possible. High suction lifts and long suction lines increase the chances of *CAVITATION*[1] and often reduce the pump flow rate.

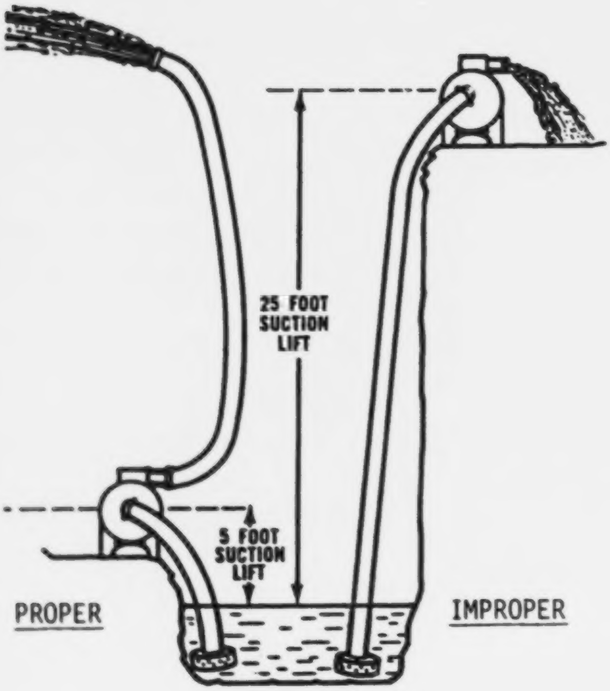


Fig. 7.4 Proper and improper suction lifts
(Permission of Homelite Textron, Charlotte, North Carolina)

7.10 Pump Types

Pump types are varied to meet different needs. Portable pumps are usually of the centrifugal or positive displacement type. This section discusses the four most common portable pumps used by treatment plant operators:

1. Centrifugal trash pump with gas driven motor,
2. Positive displacement diaphragm pump with gas driven motor,
3. Positive displacement diaphragm pump with pneumatic (air) driven system, and
4. Centrifugal submersible pump with electric driven motor.

7.100 Centrifugal Trash Pumps

Centrifugal pumps designed for use as portable pumps are often referred to as trash pumps because the water being pumped is not clean and may have solids of various sizes suspended in the water. When setting up your pump, always prime the pump with clean water. If the priming water contains soaps or detergents, problems can develop if a high suction lift exists.

Always locate the pump as near as possible to the surface of the water being pumped. A high suction lift will dramatically reduce pump discharge volume (Figure 7.4). A centrifugal pump in good condition can perform satisfactorily with a suction lift or vacuum up to 18 inches (45 cm) of mercury. This corresponds to a possible suction lift of 20 feet (6.0 m). Considerable effort is required to start portable centrifugal pumps with excessive suction lift; however, these pumps can operate with considerable suction lift at decreasing flow rates as the water level drops.

When setting up a portable pump, lay out the suction and discharge hoses as straight as possible to reduce friction losses through kinks and bends in the hoses. The suction hose has a strainer (Figure 7.5) attached to the entrance to prevent pulling rocks and debris into the pump to avoid damaging the pump or plugging the hoses or pipes. Placing the end of the suction hose in a coarse rock sump or bucket will prevent material building up on the strainer.

PUT THE SUCTION STRAINER ONTO THE END OF THE SUCTION HOSE AND NEVER PUMP WITHOUT IT.

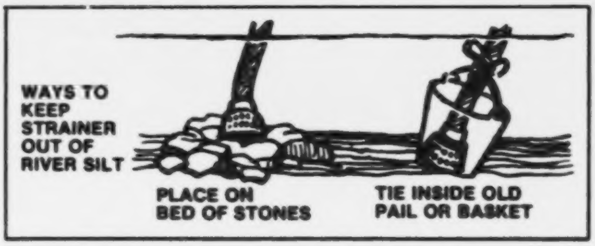

WAYS TO KEEP STRAINER OUT OF RIVER SILT
PLACE ON BED OF STONES
TIE INSIDE OLD PAIL OR BASKET

Fig. 7.5 Proper use of suction strainer
(permission of Homelite Textron, Charlotte, North Carolina)

The most frequent pumping problem is an air leak in the suction hose or a connection on the suction side of the pump. To test that the problem is not in the pump, prime the pump,

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[1] *Cavitation (CAV-i-TAY-shun). The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.*

TABLE 7.1 PORTABLE PUMP TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSE	OPERATOR RESPONSE
1. Pump engine won't start		Follow instructions in manufacturer's engine manual.
2. Pump won't prime		Test pump suction to determine if problem is inside or outside pump.
	INSIDE PUMP a. Pump needs water	Fill with clean water.
	b. Water inside pump contaminated	Drain pump and fill with clean water. Even though pump can pump dirty water, clean water may be needed for priming.
	c. Worn pump	If possible, reduce the suction lift distance. If pump cannot prime at low lift, it should be disassembled and overhauled.
	d. Diaphragm pump valves inoperative, or pump diaphragm leaking	Clean valves or replace leaking diaphragm.
	OUTSIDE PUMP a. Leaking hose or connections on suction side of pump	Make couplings tighter.
	b. Strainer clogged	Clean strainer. Try another method of keeping strainer from clogging.
	c. System clogged	Clean hoses. If necessary disassemble and clean out pump.
3. Flow is scanty	Pump OK, but too small for job	Install larger pump fitted with larger diameter hoses. If a little faster flow would be acceptable, try larger hoses with the same pump.
	Total head including friction is too great	Do everything possible to decrease the head. Try to eliminate unneeded elbows, adapters, and reducers. If possible, move pump closer to the water and shorten hoses.
	Pump leaking or worn	Overhaul pump. Have worn seals, gaskets, impeller, or housing parts replaced as necessary; or shim to reduce clearance between impeller and the wear plate or the housing.
4. Volume decreases during pumping	Roots and other debris keeping diaphragm pump valves stuck open	Elevate discharge hose so water rises to help seal valves. Keep pumping until opportunity arises to stop and clean pump.
5. Pump is "frozen" and won't move	Ice inside pump	Thaw out by gradually warming pump.
	Hard object jammed between impeller and housing	Disassemble pump and remove blockage.
6. Diaphragm pump suddenly stops; engine either quits or keeps running and pump rod slips on shaft	Solid object preventing pump rod from completing stroke	Remove discharge valve and clean cavity.
	Accumulation of grit in housing	Remove grit.

start the engine or motor, and place your hand over the suction inlet. The vacuum created by the pump should draw on your palm with a strong force if there are no leaks. You can also cap the suction inlet and install a vacuum gage on the suction side of the pump to indicate pump operation.

Portable pumps must be protected from being damaged. Whenever a hose must be laid across a roadway, lay a plank on either side of the hose. A vehicle running over the discharge hose while the pump is running may damage the hose and could also cause the pump casing to crack.

If you are operating the pump in weather that is subject to freezing, always drain the pump to prevent the freezing water from cracking the casing or binding up the pump. Before starting the pump, turn the shaft by hand to be sure that it turns freely. If the impeller is frozen fast, warm the pump slowly until the ice melts.

When water containing salt or other corrosives has been pumped, drain the pump bowl and flush with clear water. Also, rinse off the exterior of the pump. By using a slightly oiled cloth or shop towel to wipe off the exterior, you will prevent rusting of the metal. A number of small pumps have cast aluminum casings and are not as restant to corrosion as pumps having cast iron casings.

Table 7.1 is a portable pump troubleshooting guide which indicates some problems and recommended solutions.

Lubrication should be done in accordance with the pump manufacturer's O&M manual.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 545.

7.0A Support systems include what facilities or equipment?

7.1A Why are portable centrifugal pumps often referred to as trash pumps?

7.1B Why should the suction hose of a portable pump have a strainer on the end?

7.1C What precautions would you take when operating a portable pump in weather that is subject to freezing?

7.101 Positive Displacement Diaphragm Pumps

The diaphragm-type pump is a positive displacement pump. A flexible membrane (diaphragm) is used in the vertical cylinder, instead of a piston, and flap valves are used for check valves instead of the common ball checks that are used in the piston type of raw sludge pumps. The concentric movement of the rod alternates the pump from suction to pressure.

Some of the advantages of the diaphragm pump are as follows:

1. Self-priming if the suction lift is small (10 to 15 feet or 3 to 4.5 meters),
2. When primed with water, it will pump with a suction lift up to 25 feet (7.5 meters),
3. Large particles will readily pass through the pump (you may have heard of them referred to as 'mud hogs' for that reason), and
4. They are less likely to become clogged than centrifugal pumps.

The flow rate is considerably lower with a positive displacement type of pump than with a centrifugal pump. Keeping the pump close to the surface of the water being pumped will ensure maximum output.

To ensure that the pump works satisfactorily, the flap valves must seat properly. Inspect the diaphragm for leaks. If the pump will not prime, inspect the suction hose connections, flap valves, and prime water. Also look for a small hole in the diaphragm that may be causing the problem.

Taking care of the diaphragm pump is similar to the procedures outlined in Section 7.100, "Centrifugal Pumps." However, since some materials used for the membrane tend to deteriorate when exposed to long periods of sunlight, the pump should be stored in a shaded dry area.

To diagnose problems, refer to Table 7.1, Portable Pump Troubleshooting Guide.

7.102 Positive Displacement Diaphragm (Pneumatic) Pumps (Figs. 7.6 and 7.7)

Pneumatically operated diaphragm pumps can be of either the submersible or nonsubmersible type. The theory of operation in either case is quite similar.

Some of the advantages of air-powered diaphragm pumps are as follows:

1. They are resistant to wear,
2. Pumping rate may be adjusted by regulating inlet air,
3. Pump is able to run dry without damage,
4. Discharge line can be closed while pump is operating without damage,
5. Pump performance is more consistent due to less wear,
6. They are self-priming up to approximately 15 feet (4.5 m) of suction lift,
7. Some models can be submerged which results in no electrical power near the water, and
8. If you have compressed air in the plant, there is no need to purchase an additional power source.

OPERATION

There are two flexible membranes connected to a common shaft that moves simultaneously in a parallel path. The diaphragm movement is powered by compressed air directed behind one diaphragm while air is exhausted from behind the other diaphragm. When the shaft reaches its length of travel, an air valve transfers the air flow to the diaphragm in the other chamber. Air in the first chamber is then exhausted. This reciprocating action alternately creates suction and discharge of water in each chamber.

The suction and discharge valves (flap or ball type) control the flow of water in their respective cycle of operation. This form of piston-type action is similar to the piston-type positive displacement pump and the diaphragm pump.

MAINTENANCE

The pump should be flushed thoroughly after use to prevent dried sediment from obstructing valve operation. If the water pumped had large particles in it, it may be necessary to dismantle the pump to remove any remaining particles.

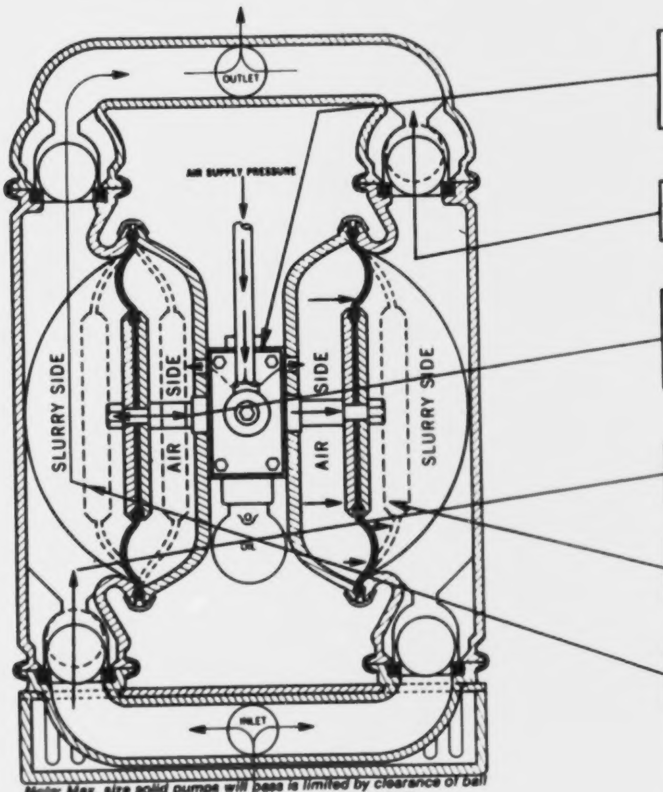
TROUBLESHOOTING

If pump will not cycle, check for:

1. Adequate air pressure,
2. Blocked discharge line,
3. Sliding air distribution valve rod hanging up,
4. Excessive air leak,
5. Plugged exhaust port,
6. Ruptured diaphragm, and
7. Open inlet valve.

If pump cycles but will not pump, check to see if:

1. Suction side of pump is pulling in air,
2. Suction line is plugged,


OUTLET
AIR SUPPLY PRESSURE
SLURRY SIDE
AIR SIDE
AIR SIDE
SLURRY SIDE
OIL
INLET

Note: Max. size solid pumps will pass is limited by clearance of ball check valve off valve seat M-4-3/16," M-8-1/4," M-15-3/8"

Patented, one moving piece air valve directs air supply pressure to back side of diaphragm

Slurry is pushed out of liquid chamber, thru pump outlet

At the same time opposite diaphragm is pulled in by rod connected to pressurized diaphragm

Suction created draws slurry into liquid chamber thru pump inlet

When pressurized diaphragm reaches limit of stroke, air valve shifts air supply pressure to back side of diaphragm which was pulled in. Slurry is pushed out of liquid chamber thru pump outlet.

On discharge stroke, pressure on both sides of diaphragm is equal & discharge pressure is equal to air supply pressure.

Fig. 7.6 Diaphragm (pneumatic) pump

(permission of Wilden Pump & Engineering Co., Colton, California)

3. Check valves (ball or flap) are not seating, and
4. Suction lift is too high.

If output flow rate is low, determine if:

1. Air pressure to pump is low,
2. Suction is restricted and accompanied by fast cycling of pump,
3. Discharge is restricted with slow cycling of pump, and
4. Valve seating is improper.

7.103 Submersible Pumps

Probably the most common type of submersible pump used in wastewater treatment plants is the 120-volt fractional horsepower motor driven centrifugal pump (Figures 29.8 and 29.9). The motor is enclosed in a waterproof enclosure sealed with 'O' rings and a mechanical seal on the output shaft. Some pumps also have a water-tight float switch attached. Floats can be adjusted to control desired liquid level.

Most pump units of this type require little maintenance. The motor bearings are sealed and will generally last the lifetime of the unit. Mechanical seals are designed with the same life expectancy. Do not run these pumps dry. This will cause wear or burning of the seal. Unless the faces match perfectly, water can enter the motor from the output shaft end and ruin the motor.

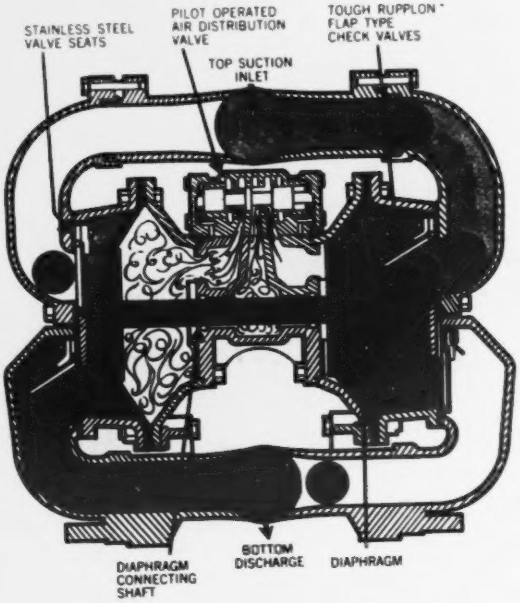

STAINLESS STEEL VALVE SEATS
PILOT OPERATED AIR DISTRIBUTION VALVE
TOUGH RUPPLON® FLAP TYPE CHECK VALVES
TOP SUCTION INLET
DIAPHRAGM CONNECTING SHAFT
BOTTOM DISCHARGE
DIAPHRAGM

Fig. 7.7 Diaphragm (pneumatic) pump

(permission of Warren Rupp Company, Mansfield, Ohio)

A. Volute bolts
B. Oil housing
C. Volute
D. Seal cartridge
E. Oil housing bolts
F. Upper seal cartridge
G. Lower bearing housing bolts
H. Lower bearing housing
I. Lower bearing cover bolts
J. Upper bearing O-ring
K. Upper bearing cover
L. Locking plate bolts
M. Stator lock screw
N. Stator
O. Stator housing
P. Junction box
Q. Housing shoulder

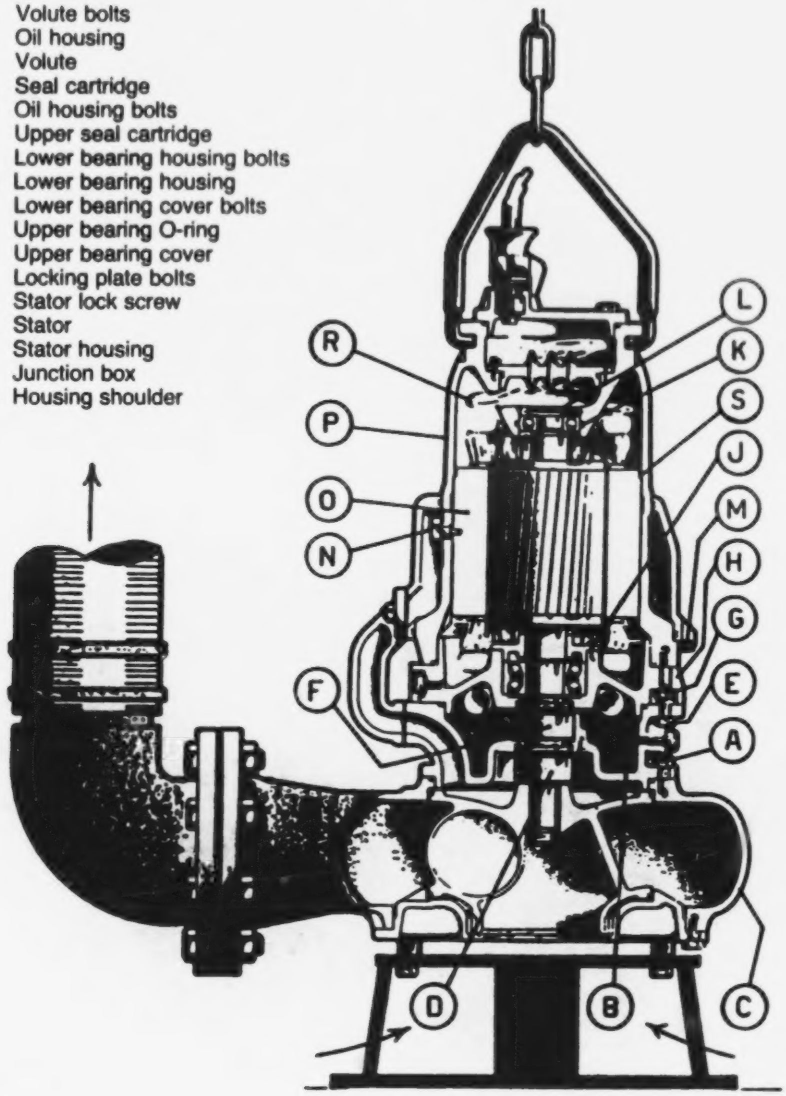


Fig. 7.8 Submersible centrifugal pump

(permission of Flygt Corp., Norwalk, Conn.)

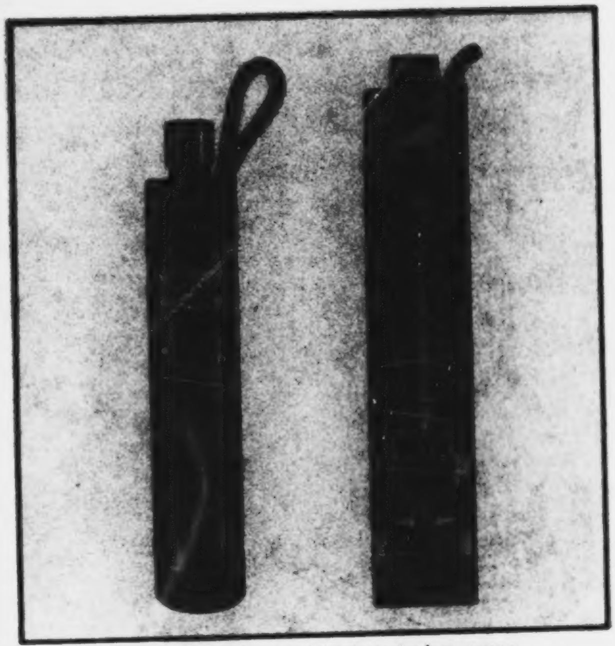


Fig. 7.9 Submersible dewatering pump
(permission of Peabody Barnes, Inc., Mansfield, Ohio)

If a submersible pump is used in a sump, periodic cleaning of the sump will insure that the pump suction will not become clogged. Larger pumps are used as portable submersibles to handle greater volumes of water. The open impeller centrifugal pump can handle wastewater containing large particles.

The closed impeller multi-stage pump is most commonly used when dewatering clear water from great depths (Figure 7.10). If you were required to remove groundwater from a construction site, a well point would be driven or set and this type of pump installed. Since conditions of head and flow vary in each instance, proper selection of the pump is very important.

7.11 Pump Engines (Refer to Section 7.4)

7.12 Seals

Most portable pumps use a mechanical-type seal between the pump housing and shaft (Figures 7.11 and 7.12). A stationary element (quite often made of a ceramic material) is "O" ring- or rubber-mounted in the pump housing. This ensures a watertight seal. The spring-loaded rotary element is fastened to the shaft with a rubber/neoprene bellows to form a watertight seal on the shaft and rides against the face of the stationary element. In many cases, the rotary element is made of carbon and is lapped to a micron finish. The rotating (and stationary) faces of mechanical seals are finished to helium light band flatness. As the pump rotates, the spring allows the rotary element to flex with shaft end play and still maintain the pressure necessary to ensure that the rotary face is in contact with the stationary element.

Mechanical seals vary in design and in the type of material used in the seal elements. These elements may be made of stainless steel, tungsten carbide, ceramic, carbon, or brass to name a few materials. Each material has its advantages and limitations. Two of the quickest ways to damage a mechanical seal are to:

1. Run it dry without water present at the seal face to dissipate heat generated by the two surfaces rubbing together. Before starting a portable centrifugal pump, always make sure that it is primed.
2. Allow dirt, grease, or dust particles to get on the faces during installation.

A number of the small seals are self-aligning. A great amount of care must be exercised in installation to insure that the seal surfaces do not become scratched or contaminated with dirt or sand. A small amount of silicone grease applied on the "O" ring will allow for ease of installation of the stationary element. The same grease when applied to the shaft will ensure a good seal with the bellows and allow the rotary element to move on the shaft initially. After the seal is in place, the bellows allows the rotary element to align itself to the stationary element.

Before you attempt to replace a seal, refer to the pump manufacturer's maintenance manual and follow the instructions. There are many differences or variables and the seals and shafts can be easily damaged if directions are not followed exactly.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 545.

7.1D List the advantages of a positive displacement diaphragm pump.

7.1E What would you do if a diaphragm pump suddenly stops pumping and the engine either quits or keeps running and the pump rod slips on the shaft?

7.1F What maintenance should be performed on a pneumatically operated diaphragm pump after use?

7.2 PIPES, VALVES AND FITTINGS

7.20 Need for Pipes, Valves and Fittings

During the process of wastewater treatment, the water is conveyed by pipes and controlled in part by valves. There are various reasons for selecting a particular type of pipe or valve. This section will discuss the common types of pipes and valves and some of their advantages and some of the limitations.

7.21 Pipes

Why specify one type (material) of pipe over another? The type installed must be selected to meet your particular needs: initial cost, durability, ease of installation, availability, compatibility with wastewater and solids being processed, and maintenance.

Pipe sizes vary and are usually specified by the inner diameter. The pipe wall thickness is designated by its strength, usually designated as pipe schedules. The schedule number is the ratio of internal pressue in PSI divided by the allowable fiber stress multiplied by 1,000. Typical schedules of iron and steel pipe are schedules 40, 80, and 160. Other forms of piping are divided to various classes with specific specification.

7.210 Galvanized Pipe

Galvanized pipe is steel pipe that has been coated with zinc by an *ELECTRO-CHEMICAL PROCESS.*[2] This zinc is a corrosion inhibitor. Most piping installations that must withstand high

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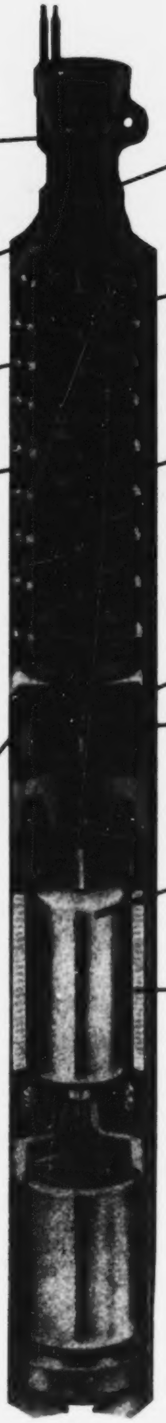
[2] *Electro-chemical process. A process that causes the deposition or formation of a seal or coating of a chemical element or compound by the use of electricity.*



New check valve with a non-deforming valve poppet closes against a smooth, tapered seat for positive, quiet action.

Barthane top bearing has shown to be 40 times more abrasion resistant than ordinary metal components.

Stainless steel pump housing and cable guard

Patented Spira-Seal system

The Spira-Seal system (a Peabody Barnes exclusive) virtually sandproves a submersible. The Barthane U-cup runs on a spiral stainless steel band around the impeller eye to form a perfect seal, eliminate recirculation, and clear sand and grit out. Tests show the seal will outlast any other now made.

Superior stage design. The Barform series cases are especially designed to deliver efficient, dependable performance. The precision molded Barform has the greatest possible resistance to abrasive action.

Stainless steel hex shaft is extra strong for a positive drive and rustproof for maximum durability.

Barform impeller is highly abrasion resistant so it will last longer and keep its surfaces and water passages smooth and efficient.

Barthane U-cup has great abrasion resistance, and it's self-compensating for all operating pressures. It remains flexible even after years of wear. (A part of the exclusive SpiraSeal system.)

Stainless steel inlet screen

Stainless steel coupling

NEMA-standard PSC oil-filled motor

Stainless steel motor shell

Fig. 7.10 Closed impeller multi-stage submersible pump

(permission of Peabody Barnes, Inc., Mansfield, Ohio)

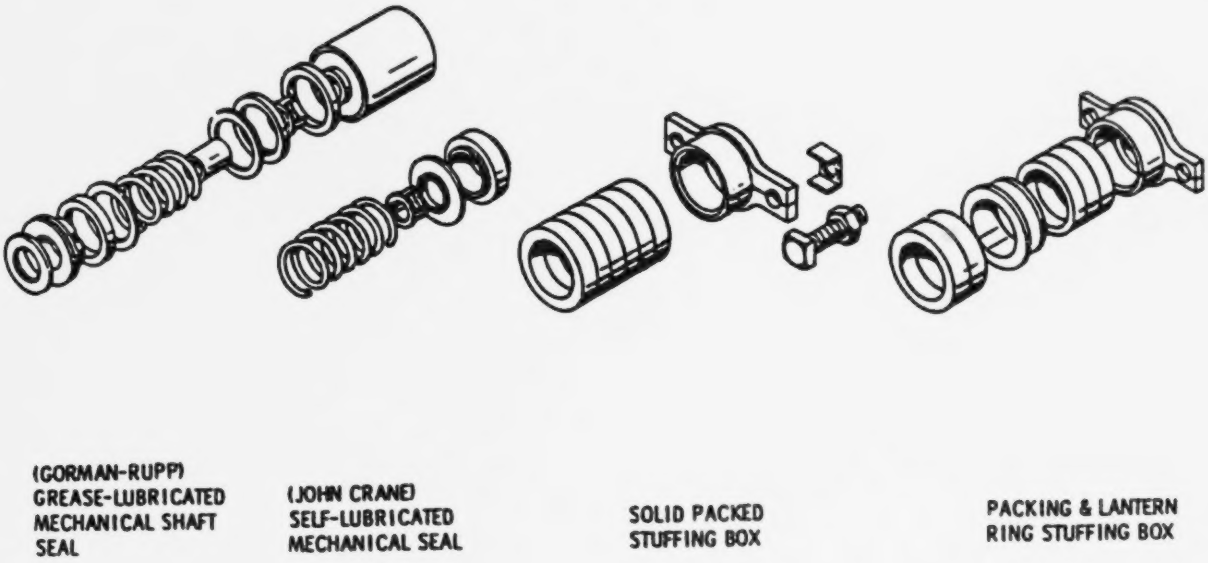

(GORMAN-RUPP)
GREASE-LUBRICATED
MECHANICAL SHAFT
SEAL
(JOHN CRANE)
SELF-LUBRICATED
MECHANICAL SEAL
SOLID PACKED
STUFFING BOX
PACKING & LANTERN
RING STUFFING BOX

Fig. 7.11 Mechanical seals
(permission of The Gorman-Rupp Co., Mansfield, Ohio)

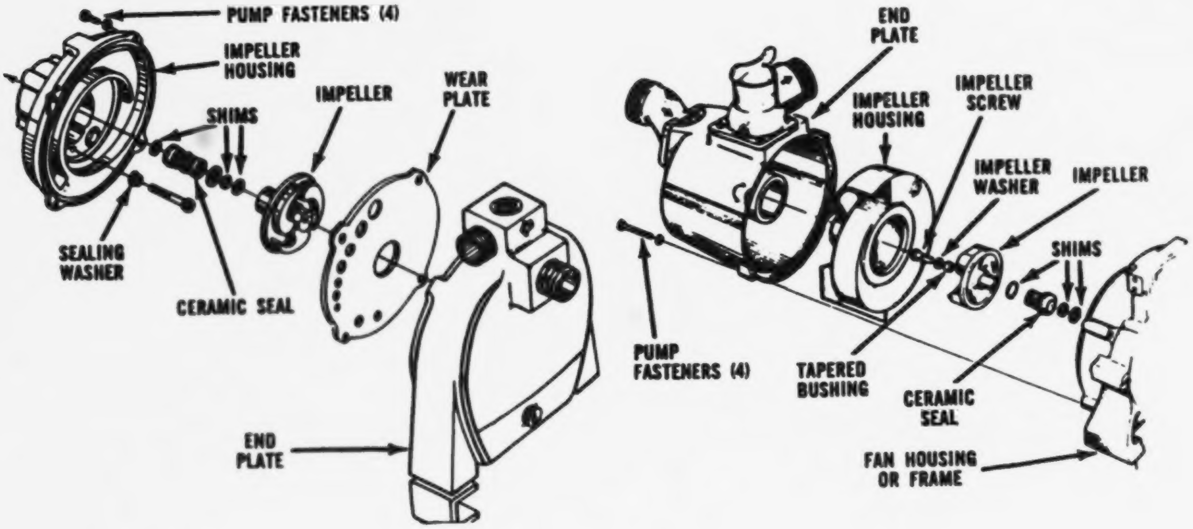

PUMP FASTENERS (4)
IMPELLER
HOUSING
SHIMS
IMPELLER
WEAR
PLATE
SEALING
WASHER
CERAMIC SEAL
END
PLATE
END
PLATE
IMPELLER
HOUSING
IMPELLER
SCREW
IMPELLER
WASHER
IMPELLER
SHIMS
PUMP
FASTENERS (4)
TAPERED
BUSHING
CERAMIC
SEAL
FAN HOUSING
OR FRAME

Fig. 7.12 Mechanical seals
(permission of Homelite Textron, Charlotte, North Carolina)

pressures are fabricated from galvanized pipe.

Schedule 40 steel pipe has a working pressure up to 175 pounds per square inch (12.3 kg/sq cm) for water, oil, or gas when used in a non-shock application not exceeding 150 degrees F (65°C). Schedule 80 can be used up to 400 psi.(28.1 kg/sq cm) of water, gas, or oil at 150 degrees F (65°C).

Galvanized pipe generally uses screwed-type fittings. Therefore, installation requires cutting and threading the pipe to correct sizes. The standard length of pipe is 21 feet (6 m) threaded on both ends with a coupler on one end and a thread protective cap on the other.

The taper of pipe threads may be designated N.P.T. (National Pipe Thread) or A.P.T. (American Pipe Thread). N.P.T. threading is by far the most commonly used threading in our industry. A.P.T. threading is generally used in special applications. One way to remember the difference between the two types of threading is to think of "normal pipe thread" when you see N.P.T.

When galvanized pipe is to be buried in soil, it is usually wrapped with a protective coating of vinyl or a tar-based product is used. This gives the pipe added corrosion protection. Many installations use a form of *CATHODIC PROTECTION*[3] to prevent *ELECTROLYSIS.*[4] Plates are imbedded in the ground and a small current is passed between the plates, thereby reducing *ELECTRO-CHEMICAL CORROSION*[5] or electrolysis.

The pipe is not affected greatly by sunlight or moderate heat or cold. The expansion and contraction is considerably less than in PVC pipe. Galvanized pipe does not fare too well in an atmosphere containing hydrogen sulfide or chloride compounds (salts or chlorine). However, painting over the galvanized surface will prolong its life.

7.211 Cast Ductile Iron/Soil Pipe

In recent years, most manufacturers have been producing ductile iron pipe instead of the true cast iron type. Ductile pipe has a greater amount of steel and better load and functional characteristics than cast iron. This pipe is of high strength and can carry high external and internal pressures (150 to 350 psi (10.5 to 24.6 kg/sq cm) working pressure). When laid in a stable soil, there are few problems with corrosion. In salt marshes, highly alkaline soil, waste dumps, or cinder fills, extra protection is provided by using plastic sheathing. Ductile iron is approximately 35 percent more resistant to corrosion than standard gray iron pipe.

When selecting ductile pipe, two items are to be considered:

1. Internal pressure of water or sludge being carried, and
2. The type and loading from the trench.

Ductile pipe is made in seven thickness classes and ranges in diameter from 4 to 48 inches (100 to 1200 mm) nominal pipe size.

Why choose ductile pipe?

1. Trench backfill (material placed and compacted over pipe in trench) is not as critical as with other types of pipes (no need for expensive import backfill material).
2. Trench loading (weight on pipe in trench) is not as critical.
3. There is less infiltration/exfiltration.
4. The pipe is available in 20 foot (6 m) lengths (few joints).
5. The pipe is durable.
6. The pipe is very effective for use in unstable and rocky soil.
7. Pipe joints are easily made.

Perhaps the largest drawback is initial price. You have to weigh its benefits for your particular application.

SOIL PIPE

Soil pipe is a thin wall or light weight cast iron pipe. This pipe has been used extensively in drainage lines. Soil pipe also has corrosion resistance similar to the large cast pipes. One of its drawbacks is that it breaks easily. It has a low load-bearing weight and is commonly used in a gravity-flow situation. Under normal conditions, it will fare quite well.

7.212 PVC (Polyvinyl Chloride) Pipe

The cost of maintenance, repair, and replacement of underground piping caused by corrosion is very important. PVC pipe is immune to nearly all types of corrosion, be it biological, chemical, or electro-chemical. Since PVC is a non-conductor, galvanic effects are non-existent and provisions for cathodic protection as required with steel and cast iron systems are unnecessary for PVC systems.

In wastewater collection lines, internal corrosion caused by sulfuric acid (a result of the hydrogen sulfide cycle) takes its toll on asbestos cement, concrete, and metal pipes. PVC is not affected by sulfuric acid in concentrations found in sanitary sewers. PVC is resistant to biological attack and will not decay. Metal pipes are slowly destroyed by oxidation. Bacteria and other microorganisms will not cause deterioration of PVC pipe. The wear characteristics of PVC are exceptional and it is resistant to abrasion. Since the interior of the pipe is smooth, there is less friction loss than with other types of pipes.

There are, however, some drawbacks to PVC pipe that should be considered also. PVC will deteriorate when exposed to ultra-violet radiation. Painting the pipe will help deter the effect. PVC pipe will flex, expand, and contract with heat. This may be a problem in certain applications.

The smaller sizes of PVC pipe are not expensive when compared to galvanized or steel pipe; however, this is not so as the size increases. PVC is very easy to install and no special tools nor highly skilled workers are necessary. Consult with your pipe vendor to insure that the proper class or schedule of PVC is being used for a particular application.

7.213 Concrete Pipe

To move large volumes of wastewater in gravity sewer systems, we must be able to install pipe of large sizes that is structurally strong, reasonably corrosion resistant, and available at an acceptable price. Concrete pipe meets these qualifications. Most large concrete pipes are reinforced with reinforcement bar. This adds to the load strength that the pipe can bear. When a line is 15 to 20 feet (4.5 to 6.0 m) below the surface, it has to withstand great external pressures. Concrete pipe is not adversely affected by most soil chemicals. However, it must be laid in an engineering trench and backfilled under specified conditions.

Internal pipe corrosion in a domestic wastewater system is one of concrete pipe's limitations. As hydrogen sulfide gas escapes from the wastewater, it combines with bacteria in the slime that coats the pipe interior. The bacteria convert the gas into sulfuric acid. If the pipe is of a corrodible material, such as concrete, the sulfuric acid slowly decomposes the concrete. When the pipe is full and moving at an acceptable rate, deterioration from sulfuric acid is kept at a minimum. Deterioration of concrete pipe can be slowed if the pipe is made of calcereous cement which is high in lime that will help to neutralize the sulfuric acid.

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[3] *Cathodic Protection (ca-THOD-ick). An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.*

[4] *Electrolysis (ELECT-TROLLY-sis). The decomposition of material by an electric current.*

[5] *Electro-chemical Corrosion. The decomposition of a material by (1) stray current electrolysis, (2) galvanic corrosion caused by dissimilar metals, and (3) galvanic corrosion caused by differential electrolysis.*

With concrete pipe, there is a greater chance of infiltration/exfiltration than with other types of pipes; however, this is usually not a problem.

7.214 Asbestos — Cement Pipe

Asbestos-cement pipe is made of asbestos, sand, and Portland cement. When combined with cement, the long asbestos fibers yield a pipe of considerable strength. This pipe will accept high external loads as well as being able to operate with a pressured fluid. Asbestos-cement pipe is very corrosion resistant. There are no electrolysis effects, either chemical or electro-chemical, and it fares well in salt or alkaline soil.

The interior of the pipe is smooth and has less friction loss than standard concrete pipe. Since the standard length of pipe is 13 feet (4 m), there are fewer joints. Asbestos cement pipe weighs less than comparable sizes of concrete or tile pipe and is cheaper to transport. However, the initial cost of asbestos-cement pipe is greater than the price of concrete pipe. As with concrete pipe, trenching and backfill must be engineered. Generally, asbestos-cement pipe is not used in rocky areas without proper pipe bedding.

7.215 Welded Steel Pipe

Welded steel pipe is available in sizes ranging from ½ inch to 42 inches (12.5 to 1,050 mm). In sizes ½ inch through 12 inches (12.5 to 300 mm) of standard pipe, the inside diameter is of the nominal pipe size. However, in sizes 14 to 42 inches (350 to 1,050 mm), the dimension refers to the outside diameter of the pipe.

Sizes from 1 to 12 inches (25 to 300 mm) are available in four different wall thicknesses (ST, XS, 160, and XX). In sizes 14 to 42 inches (350 to 1,050 mm), it is available in ST and XS thicknesses only. To see how the pipe schedule is directly related to wall thickness, the specifications for one-inch (25 mm) pipe are listed below:

	Wall Thickness, in/mm				
Pipe Size	**Outside Diameter**	**ST Schedule 40**	**XS Schedule 80**	**Schedule 160**	**XX Strong**
1 inch	1.315	0.133	0.179	0.250	0.358
25 mm	33.40	3.38	4.55	6.35	9.09

Welded steel pipe is very versatile because it can be cut and welded to follow varied contours. This is very helpful when aligning pumps and other pumping-related equipment. Welded steel pipe allows closer nesting of pipes when space is at a premium. Less space is required for welded fittings than flanges and bolts; however, space must be available when welding the joints.

This pipe provides permanent leak-proof connections via welding. An advantage of welded steel over threaded pipe is the fact that none of the pipe wall has been reduced by the cutting in of threads (the threaded joint is susceptible to corrosion and loosening by vibration) and uniform wall thickness is maintained. In comparison to most other metallic pipes, welded pipe systems are easier to install and do not require the heavy and costly tools needed to install other conventional systems.

Welded steel pipe is not very resistant to corrosion. Therefore, it is necessary to coat the pipe with a bituminus product. The interior of the pipe is often coated to prevent corrosion caused by the materials being transported.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 545.

7.2A Galvanized pipe is subject to corrosion in what types of atmospheres?

7.2B How can galvanized pipe be protected from corrosion?

7.2C What types of locations might cause ductile iron pipe to corrode?

7.2D What is a major limitation of concrete pipe?

7.22 Valves

7.220 Use of Valves

Valves are the controlling devices placed in piping systems to stop, regulate, check, divert, or otherwise modify the flow of liquids or gases. There are specific valves that are more suitable for certain jobs than others. The five most common valves that you will find in a wastewater treatment facility are discussed in this section.

7.221 Gate Valves (Figures 7.13 and 7.14)

The basic parts of a gate valve are: the operator (handle), the shaft packing assembly, the bonnet, the valve body with seats, the stem, and the disc. Gate valves come in a large number of sizes, but the principle of operation is quite similar. One could associate the action of a gate valve to that of a guillotine having a screw shaft instead of the rope. The valve disc is raised or lowered by a threaded shaft and is guided on each side to ensure that it will not hang up in the operation. The disc is screwed down until it wedges itself between two machined valve seats. This makes a leakproof seat on both sides of the disc. The discs are replaceable. Some gate valves have discs with wedges inside. As more force is applied to the screwed stem, the wedges force the discs into tighter contact with the valve seats. The flow should go in the direction of the arrow on the gate valve.

Gate valves are either of the rising (Figure 7.13) or non-rising stem (Figure 7.14) type. The rising stem has companion threads in the valve bonnet. As the valve is opened, the stem is threaded out, lifting the wedged disc. In the non-rising type, the stem is held in place in the bonnet by a collar. The stem is threaded with companion threads in the wedged disc. As the valve opens, the disc rises on the stem. Consequently, the hand wheel stays on the same plane.

Gate valves are not commonly used to control flows. With the valve partially open, the water velocity is increased through the valve. Minute particles transported in the water can cause undue seat wear. The vee-ported gate valve can be used in controlling flows. As the valve is opened, the vee is widened to allow more flow. Because of the valve design, little damage is done to the valve seats in the vee-ported type of gate valve.

Suggested operation and maintenance procedures are listed below:

1. Open valve fully. When at stop, reverse and close valve one-half turn.
2. Operate all large valves at least yearly to insure proper operation.

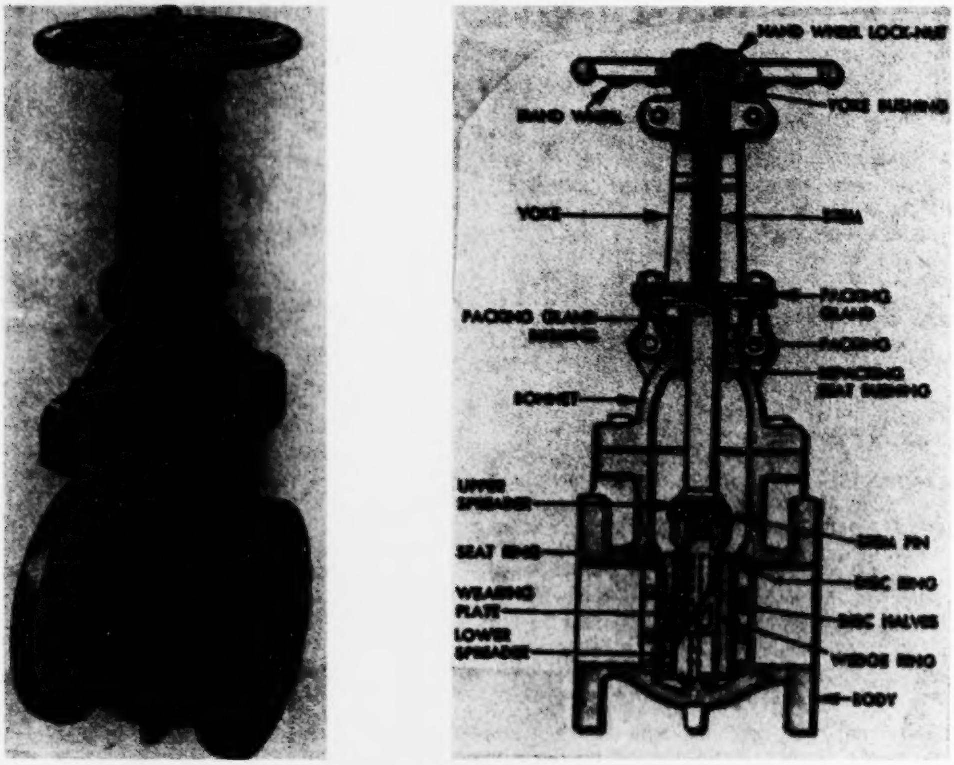
HAND WHEEL LOCK-NUT
HAND WHEEL
YOKE BUSHING
YOKE
STEM
PACKING GLAND BUSHING
PACKING GLAND
PACKING
REPACKING SEAT BUSHING
BONNET
UPPER SPREADER
STEM PIN
SEAT RING
DISC RING
WEARING PLATE
DISC HALVES
LOWER SPREADER
WEDGE RING
BODY

Fig. 7.13 Rising Stem Gate Valve
(permission of Stockham Valves & Fittings, Copyright, 1976)

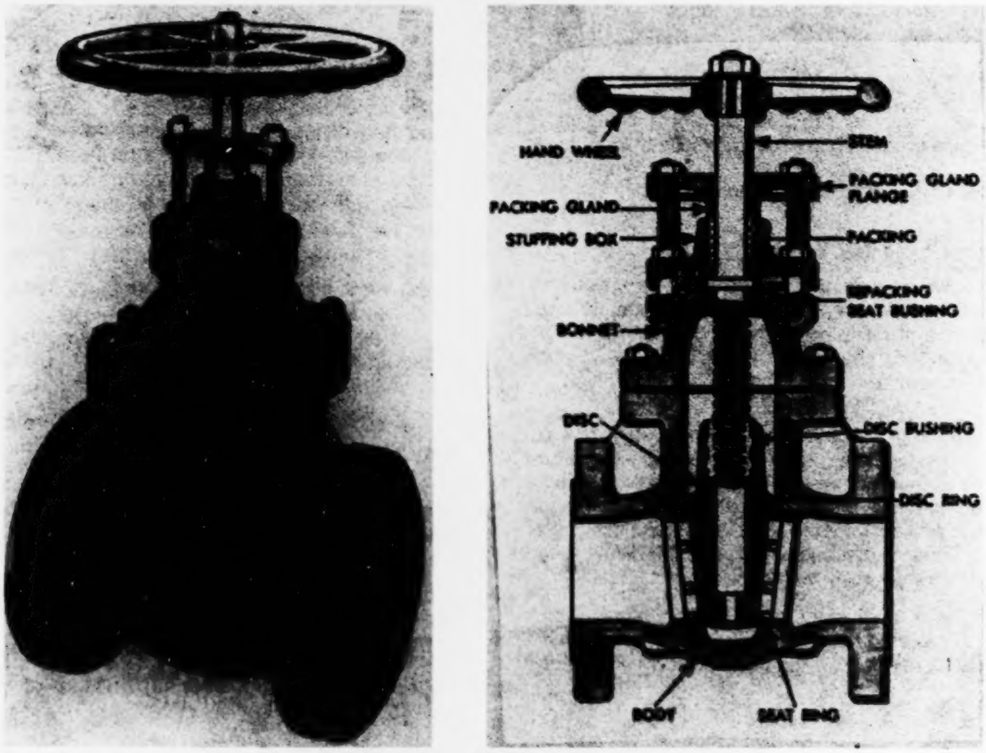
HAND WHEEL
STEM
PACKING GLAND FLANGE
PACKING GLAND
STUFFING BOX
PACKING
REPACKING SEAT BUSHING
BONNET
DISC
DISC BUSHING
DISC RING
BODY
SEAT RING

Fig. 7.14 Nonrising Stem Gate Valve
(permission of Stockham Valves & Fittings, Copyright, 1976)

3. Inspect valve stem packing for leaks. Tighten as needed.
4. If the valve has a rising stem, keep stem threads clean and lubricated.
5. Close valves slowly in pressure lines to prevent *WATER HAMMER.*[6]
6. If a valve will not close by using the normal operation, check for the cause. Using a 'cheater' (bar-pipe wrench) will only aggravate your problem.

7.222 Globe Valves (Fig. 7.15)

The globe valve seating configuration is quite different from the gate valve. Globe valves use a circular disc to make a flat surface contact with a ground-fitted valve seat. This is similar to placing your thumb over the end of a tube. The parts of the valve are similar in name and function to the gate valve. They can be of the rising or non-rising stem type.

What is unique about the globe valve is its internal design (Fig. 7.15). This design enables the valve to be used in a controlling mode. The valve seats are not subject to excessive wear when partially opened like the gate valve. After extended use, the valve may not have a positive shut off but it will still be effective in throttling flows. Procedures for operating and maintaining globe valves are similar to the procedures outlined for gate valves in Section 7.221.

7.223 Eccentric Valves (Figures 7.16 and 7.17)

The eccentric valve has many desirable features. These features include allowance for high flow capacity, quarter turn operation, no lubrication, excellent resistance to wear, and good throttling characteristics. The eccentric valve uses a cam-shaped plug to match an eccentric valve seat. As the valve is closed, the plug throttles the flow yet maintains a smooth flow rate. The plug does not come into contact with the valve seat until it is in the closed position.

Because the plug has a resilient coating, it insures a leak-tight seal at the valve seats. The Buna-N, neoprene, or viton plug coating is very wear resistant and can function well under a wide temperature range. This valve is excellent for controlling the flows of slurries and sludges found in wastewater treatment facilities.

7.224 Butterfly Valves (Fig. 7.18)

The butterfly valve is used primarily as a control valve. The flow characteristics allow the water to move in straight lines with little turbulence in the area of the valve disc (butterfly). Complete flow shutoff can be accomplished but the PSI rating is relatively low in comparison to eccentric or gate valves.

The butterfly valve uses a machined disc that can be open to 90 degrees to allow full flow through the valve. Quarter turn operation moves the valve from the 'closed' to 'open' position. The disc is mounted on a shaft eccentric that allows the disc to come into its seat with minimum seating torque and scuffing of the rubber seat. There is no contact between the disc and the seat until the last few degrees of valve closure.

A resilient rubber is used as the seat and is of a continuous form that is not interrupted by a shaft connection. Wear resistance characteristics are good when used in slurry and sludge applications.

When the valve is closed, the disc is forced against the rubber seat. Wedges with jacking screws compress the rubber seat via a jack ring. The rubber seat then conforms to the entire disc circumference. The rubber can be readily replaced when necessary without complete valve dismantling. Large valves do not need to be removed from the line for seat replacement.

7.225 Check Valves (Fig. 7.19)

The term 'check valve' describes its function. A check valve allows water to flow in one direction only. If the water attempts to flow in the opposite direction, an internal mechanism closes the valve and "checks" the flow. Three types of check mechanisms may be used — the swing check, the wafer check, or the lift check. In the swing check, a moveable disc rests at a right angle to the flow and seats against a ground seat. The moveable disc is called the clapper. The clapper can be one of three types: gravity operated, lever and weight operated, or lever and spring operated. In many installations the water being pumped must be delivered at a desired flow rate and pressure. A clapper with an external means of adjusting the opening in the check valve may be necessary to produce desired flows and pressures. By positioning the weight on the lever or adjusting the spring tension, a check valve can be made to operate either partially or fully open at various pressures and flows. The spring or counter weight also ensures that the check valve closes at "no flow." This is very helpful if the valve is not in a position that will enable gravity alone to operate the clapper. The gravity-operated clapper does not have an external adjustment and relies on the weight of the clapper to close the valve at "no flow" conditions.

Most swing check valves provide for full opening, that is, the clapper can move up into the bonnet and thus be completely out of the flow. Head loss in swing check valves may be relatively high and this factor must be considered in selecting the device for a particular application. This type of check valve is quite common in pump installations and often has a dampening feature to cushion the closing of the clapper.

The wafer check has a circular disc that hinges in the center (diameter) of the disc. Water passing through collapses the disc and the stoppage of flow allows the disc to return to its circular form. Because the valve has a tendency to be fouled up by stringy material, it is not commonly used in handling domestic wastewater. Wafer check valves are very effective when used with clean water.

The lift check uses a vertical lift disc or ball. When there is flow, the disc or ball is lifted from its ground seat and fluid passes through the valve. As flow stops, the check realigns itself with its seat and checks or prevents water backflow. The moveable portion can be a spring or gravity return.

The foot valves used in pump suctions are nearly always of the vertical lift disc design. A check valve of this type is usually applied to handle clean water.

Backflow prevention by check valves is essential in many applications to:

1. Prevent pumps from reversing when power is removed,
2. Protect water systems from being cross-connected,
3. Aid in pump operation as a dampener, and
4. Insure "full pipe" operation (pipe is full of water).

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[6] ***Water Hammer.*** *The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.*

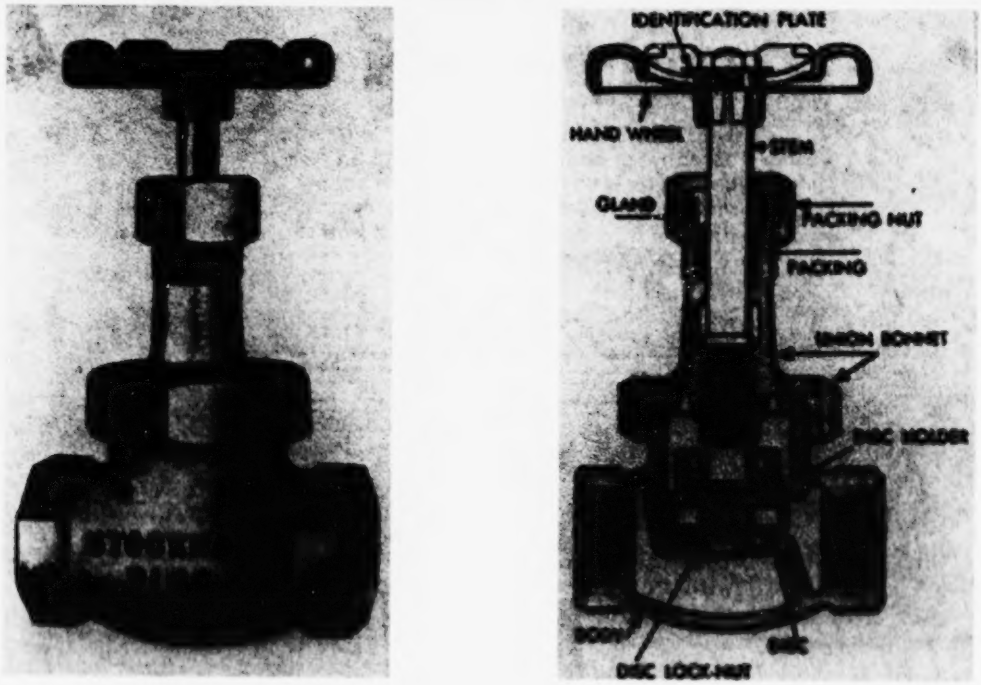


Fig. 7.15 Globe Valve

(permission of Stockham Valves and Fittings, Copyright, 1976)

7.23 Fittings for Steel, Ductile and Cast Iron Pipes

This section describes fittings that are used in piping systems that handle special needs.

7.230 Victaulic Couplings (Figs. 7.20a and 7.20b)

The victaulic coupling is a two-piece bolted unit with a sealing gasket. The victaulic coupling is used in an area where future disassembly is anticipated. Quite often you will find them on the suction and discharge sides of pumps. Two bolt couplings are much easier to remove than a bolted flange. Two grooves are machined into the two pieces of pipe being coupled. The cast coupling collar locks into the grooves. A one-piece rubber neoprene gasket makes a seal between the outside of the two pieces of pipe being secured in place by the collar.

The victaulic coupling will allow for a small amount of misalignment between pipes. Its primary use is for a quick, easy coupling of two pipes and to serve as an expansion joint and a vibration depressor.

7.231 Sleeve Coupling

The sleeve coupling consists of a steel tube with a slight flare on the inside of both ends. This is to accommodate the wedged resilient gasket. The sleeve coupling is compressed against the pipe by pulling two flanges together with bolts and nuts. Two pieces of pipe generally of the same size are joined together. This type of coupling also will allow for some misalignment as well as expansion. A sleeve coupling is ideal to use when joining two unflanged pipes in an area where space is at a premium. This coupling is fast, sure, and easy to install.

There are a number of variations in sleeve couplings:

1. A transition coupling enables you to connect two sizes (¾-inch or 19 mm variance) or two dissimilar pipes (cast to steel-cast to PVC);
2. A reducing coupling allows two sizes of pipe to be coupled; and
3. A 'cut-in' repair coupling enables you to remove a small damaged area of a pipe and couple the new piece to the old pipe.

7.232 Compression Coupling

The compression coupling consists of a tube threaded on each end for the compression nuts and two tapered sealing grommets. As the nuts at either end are tightened, the sealing grommet is compressed until a watertight seal is accomplished. This type of coupling is used to allow for misalignment of the two pipes being connected. When faced with joining two pipe ends that are close together but cannot be coupled by a standard union, the compression coupling fills the need. This coupling is a reliable threadless connector.

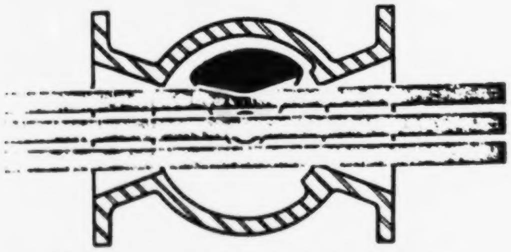
When installing, make sure that pipe wrench jaw marks are smoothed down with a file so grommets have a smooth sealing surface.

7.233 Mechanical Flanges

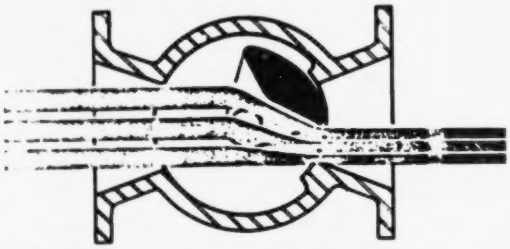
Mechanical flanges are used to connect unflanged pipes to flanged fittings (tees, 90-degree bends, valves). One side of the flange is secured to the pipe by a resilient gasket that is compressed by a bolt-tightened compression flange (by mechanical means). The other end of the flange has a bolt hole pattern that matches the flange being coupled to. A mechanical flange simplifies the installation of complex piping systems

ECCENTRIC ACTION

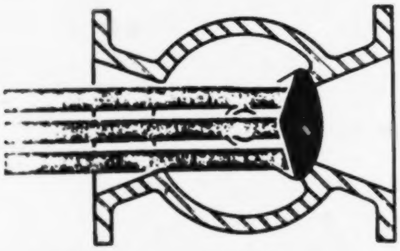
The DeZurik design matches a single-faced eccentric or cam-shaped plug with an eccentric raised body seat. With rotary motion only, the plug advances against the seat as it closes. Here's how it works:



OPEN—The plug is out of the flow path. There is no bonnet or other cavity to fill with slurry material. Flow is straight-through with minimum pressure drop.



CLOSING—At any position between open and closed, the eccentric plug still has not touched the seat. There is no friction to cause wear or binding. Flow is still smooth and straight. Throttling action is excellent on all types of services from slurries to gas.



CLOSED—The eccentric plug makes contact with the eccentric seat only in the fully closed position. Action is easy, without binding or scraping. There is no continual seat wear. The plug is moved firmly into the seat to provide a positive, drip-tight, long-lasting seal.

Fig. 7.16 How eccentric valves work

(permission of DeZurik Corporation, Sartell, Minnesota)

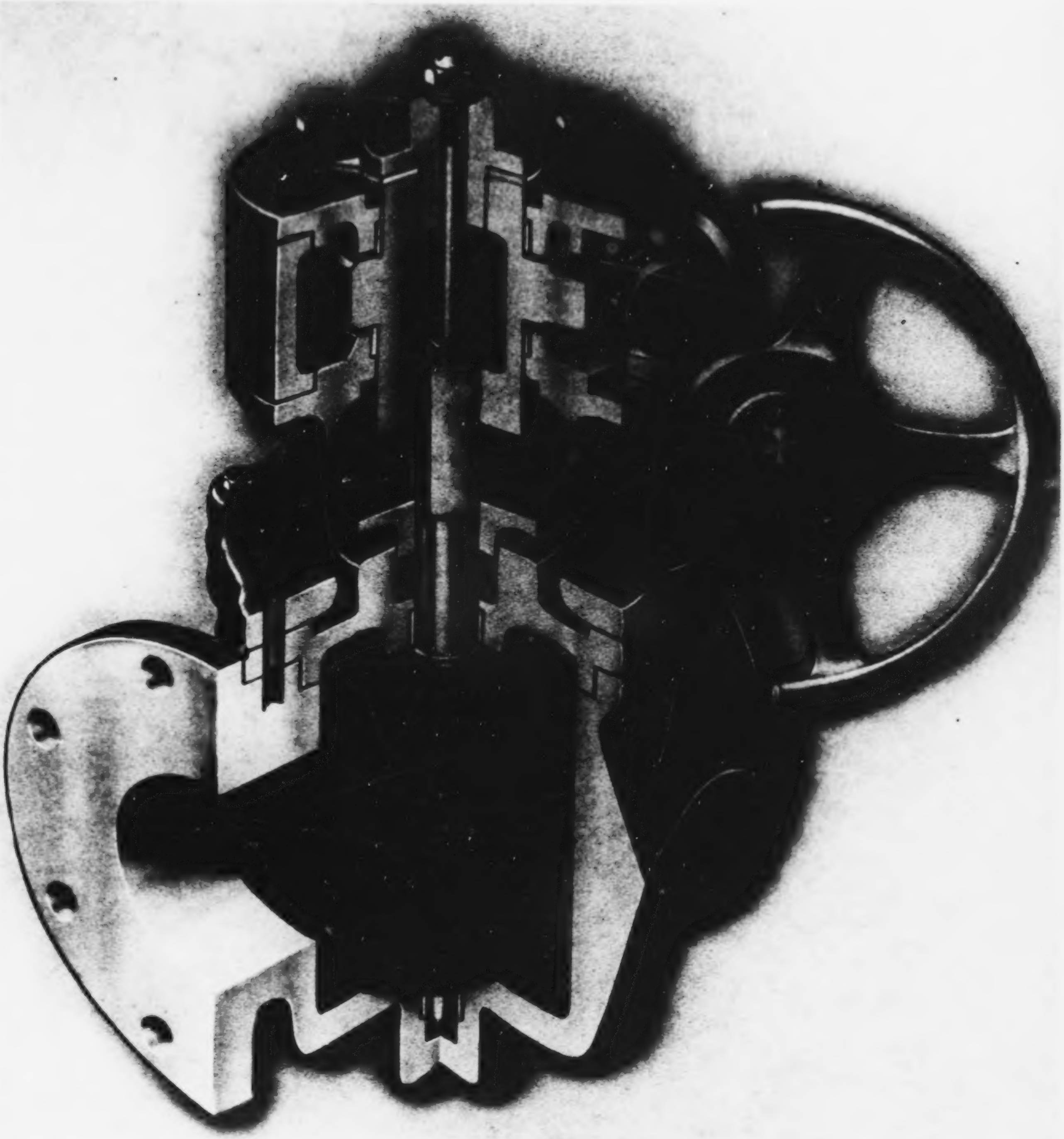


Fig. 7.17 Eccentric valves
(permission of DeZurik Corporation, Sartell, Minnesota)

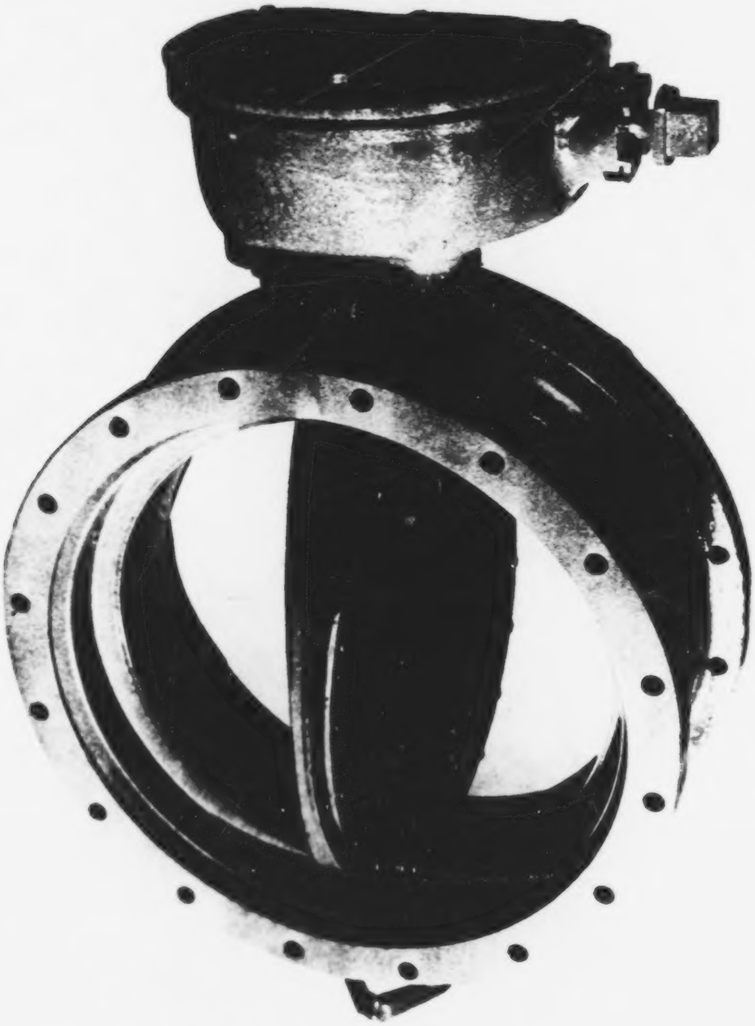
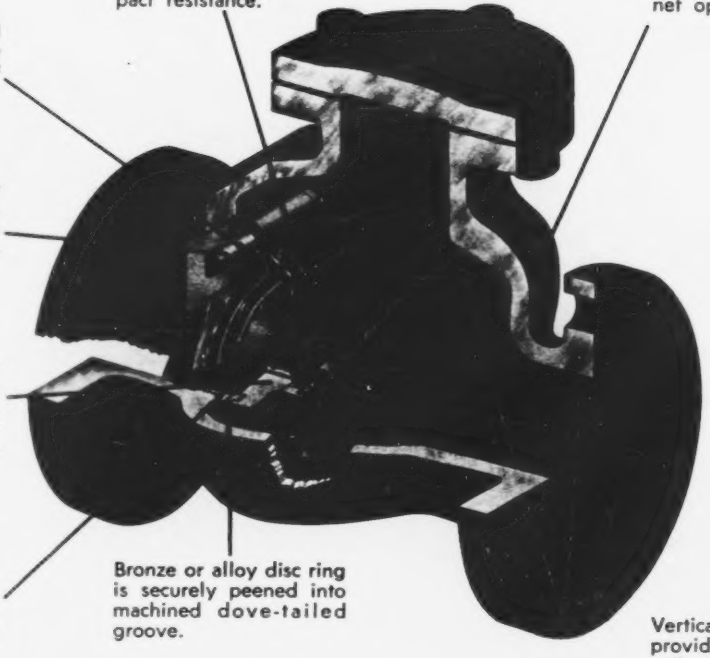


Fig. 7.18 Butterfly valve

(permission of American-Darling Valve, Birmingham, Alabama)



Bronze bushed ductile iron clapper arm for added strength and impact resistance.

Body design permits removal of clapper arm assembly through bonnet opening.

Tight closing assured since clapper arm shaft is set slightly back of vertical seat face.

Bronze clapper arm shaft can be extended through body when lever with weight or spring is required.

Fully revolving disc seats in different position on seat ring face and distributes wear uniformly over the entire seating face.

Bronze seat ring is screwed in body and made with lugs and can be replaced with body in line. It can be furnished with a resilient insert for bottle-tight service on gas or air.

Bronze or alloy disc ring is securely peened into machined dove-tailed groove.

Vertical seating surfaces provide sensitive seating action.

Fig. 7.19 Check valve

(permission of American-Darling Valve, Birmingham, Alabama)

FOR GROOVED END PIPE

Standard Coupling: Sizes ¾"-24"

Style 77

General purpose. Best suited to the average conditions under which steel, spiral and other IPS pipe is installed.

Rigid Couplings: Sizes 2"-12"

Style HP-70

Uniquely designed for varied rigid services. Tongue-and-recess design assures proper mating of housing and provides protection from gasket extrusion.

Endseal Coupling: Sizes 2"-12"

Style HP-70ES

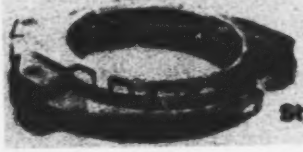
For high pressure service. The ENDSEAL gasket is molded of a specially formulated and compounded oil-resistant Buna-N, with high modulus for resistance to extrusion.

Lightweight Coupling: Sizes 2"-8"

Style 75

For light duty applications where relatively low pressures, low external stresses and lightweight materials are controlling factors.

Snap-Joint Couplings: Sizes 1"-8"



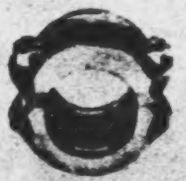
Style 78

Designed for pipe lines where quick "Make and Break" of pipe joints is important.

Fig. 7.20a Victaulic couplings (for grooved end pipe)
(Permission of Victaulic Company of America)

FOR PLAIN END PIPE

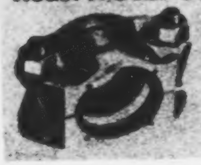
Plainlock Coupling: Sizes 1"-6"



Style 90

For use as line joints wherever grooved end pipe is not available. Quick and easy to install by use of simple socket wrench.

Roust-A-Bout Coupling: Sizes 1½"- 12"



Style 99

Same use as PLAINLOCK except for heavy duty service. "Built-in" jaws of hardened steel give up to twice the gripping contact provided by ordinary grips.

Fig. 7.20b Victaulic couplings (for plain end pipe)
(Permission of Victaulic Company of America)

since there is no need to thread large pieces of pipe and flange-bolt holes are easy to align.

7.234 Band Seals

The 'band seal' is a rubber coupling that is used to join clay, soil pipe, or asbestos-cement pipe. A flexible rubber coupling is secured to the two pieces by stainless steel screw clamps (it looks like a large radiator hose clamp that compresses the rubber and ensures a leak proof-seal). This type of connection is widely used in gravity flow sewer piping systems. Band seals allow for maximum deflection of the two adjoining pipes. They are easy and economical to use.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 545 and 546.

7.2E What is the purpose of valves?

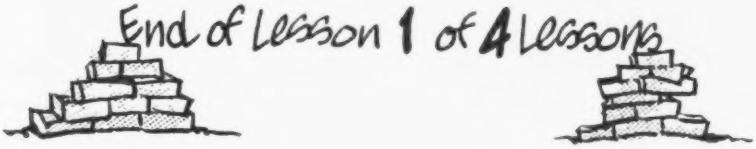
7.2F List the five most common types of valves found in wastewater treatment facilities.

7.2G What is the purpose of a check valve?

7.2H Why is backflow prevention by check valves essential in many applications?

7.2I Where are victaulic couplings used?

7.2J Under what conditions are band seals installed?


End of Lesson 1 of 4 Lessons

Please answer the discussion and review questions before continuing with Lesson 2.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 4 Lessons)

Chapter 7. MAINTENANCE

Write the answers to these questions in your notebook before continuing.

1. Why should operators know how to operate and maintain support systems?
2. Why should you locate a portable pump as near as possible to the surface of the water being pumped?
3. How would you determine if there is an air leak in the suction hose of a portable pump?
4. What can happen if a submersible pump with a mechanical seal is allowed to run dry?
5. What factors would you consider when selecting the type (material) of pipe to do a particular job?
6. What factors can cause wear on gate valve seats?

CHAPTER 7. MAINTENANCE

(Lesson 2 of 4 Lessons)

7.3 AUXILIARY ELECTRICAL EQUIPMENT

7.30 Safety First

This section covers some aspects of electrical equipment that have not been covered in previous chapters. Bear in mind that a *QUALIFIED ELECTRICIAN* should perform most of the necessary maintenance and repair of electrical equipment. If you don't know the how, why, and when of the job, don't do it. You could endanger your life as well as your fellow operators. Never attempt work that you are not qualified to do or are not authorized to perform.

7.31 Standby Power Generation

Because the treatment of wastewater is considered a critical service, it is imperative to have that function continue even with loss of commercial power. A power outage of a short duration probably will not have adverse effects on plant operation. The question you must ask yourself is, "Can your plant meet the needs of the public if a 'brown out' or an earthquake occurs that eliminates commercial power for an extended length of time?" If the answer is 'no,' then perhaps a form of standby power generation should be considered.

Where do you begin? You have to consider whether you would like to have all of your facility operating or whether just the vital or key equipment would be sufficient. Since the characteristics and operating conditions of every plant are different, it is extremely difficult to make specific suggestions.

For the sake of illustration, let us pose a hypothetical situation. Consider a 10 MGD (38,000 cu m/day) capacity plant with an average flow rate of 6 MGD (23,000 cu m/day) and a trickling filter for secondary treatment. If you wanted to ensure minimal operation, prepare a list of needs that must be met:

1. Comminution,
2. Wastewater pumping,
3. Clarification,
4. Trickling filter circulation,
5. Sludge handling,
6. Chlorination/dechlorination, and
7. Minimal lighting.

Calculate the maximum horsepower or total kilowatts necessary to maintain the limited operation:

1. Comminutor — 3 horsepower	2.24 KW
2. Wastewater Pump — 75 horsepower	56. KW
3. Clarification — 2-1.5 horsepower	2.24 KW
4. T.F. Circulation — 40 horsepower	30. KW
5. Sludge Handling — 30 horsepower	22.40 KW
6. Chlorination — 15 horsepower	11.20 KW
7. Lighting	5. KW
	129.08 KW

The minimum power required is 129.08 KW. When sizing a generator for emergency power, you have to make sure that the generator will be able to start the needed motors. Since the locked rotor current of the 75 horsepower induction motor on the wastewater pump is approximately four times running current, then the generator must be able to handle 224 KW at that instant. Size the generator not only by total load, but also for the highest horsepower motor being started. Consider the sequence in which motors will be started. The starting of all the motors simultaneously (without sequence starting) would be nearly impossible. Consult experts in power generation for answers to your specific questions regarding your plant because each plant has different needs. If you are considering standby power, shop around and get ideas from the equipment manufacturers.

After you have determined the size of generator needed, you must be able to connect it to your power distribution system. This may require some sophisticated switch gear. Besides the mechanical functions necessary in connecting the emergency power with your normal system, it is important that the two systems cannot be electrically coupled. (Two electrical systems must be 'in phase' with each other before parallel coupling.) For this reason mechanical interlocks are used to insure that one circuit is always open. A "kirk-key" system, where one key is used for two locks, locking one switch open before the other can be closed, is sometimes used.

Looking back at the plant described, a generator of 150 KW with intermittent overload capabilities should handle the load. (Note: This is an assumption. Actual calculation may indicate a different size.) An engine-generation system of this size could handle your minimal power needs. If your wastewater collection system has ample capacity, it may be possible to throttle your influent gate, backing up flow and allowing it to enter the plant at a flow rate you can handle. Be careful not to flood any homes, businesses, or streets. With a variable-speed influent wastewater pump capable of pumping 5,500 GPM (30,000 cu m/day), you would be able to catch up with the flow during the off peak flow periods.

If you do not have standby power generation at your facility, talk to others in the treatment field that do and obtain ideas and information. After due consideration, take the necessary steps to ensure yourself against interrupted power.

7.32 Emergency Lighting

7.320 Types of Equipment

The most practical form of emergency lighting in most instances is that provided by battery-powered lighting units. Because they are used primarily for exit lighting, they are more economical than engine-driven power sources. If you have a momentary power outage, the system responds without an engine-generator start-up. All emergency lighting unit equipment is basically the same and consists of a rechargeable battery, a battery charger, low voltage flood lights, and test monitoring and control accessories. Proper selection of a unit for a particular location requires careful consideration of the following items:

1. Initial cost,
2. Types of batteries,
3. Maintenance requirements, and
4. Lighting requirements.

The three types of batteries most commonly used are: lead acid, lead calcium, and nickel cadmium. Because poor battery maintenance is quite common in emergency lighting systems, "maintenance free" batteries are becoming increasingly popular. These batteries can have a gelatin or acid (wet) *ELECTROLYTE*.[7] The gelatin type is completely spillproof and can be handled safely without the dangers of acid spills. These batteries have a shorter life span than the wet type. Since all batteries undergo evaporation, the gelatin electrolyte will be exhausted before that of a battery containing liquid. Wet-type maintenance free batteries require no refilling and, when handled porperly, acid spillage is minimal.

In terms of cost, the maintenance-free battery is more expensive; but when you consider the human factor, they may be more reliable and cheaper in the long run. Most systems use a battery charger that monitors the battery voltage. When required, the charger then charges the batteries. In earlier designed units, a trickle charger was used. This constant charging resulted in inoperative batteries in a short time because of overcharging.

The lamps used are normally 6 to 12 volt sealed-beam 25-watt lamps. The light pattern provided is most effective when illuminating a work area. A rule of thumb is that one lamp will be sufficient for about 1,000 square feet, providing that the full light pattern can be used. Consult emergency light level codes (Table 7.2) for your particular application.

When selecting an emergency lighting system, check it very thoroughly to insure that it will give you the protection needed. If it fails to work when the chips are down and the main power is out, you've wasted your money.

7.321 Batteries

This section will discuss wet storage batteries since they are the most prevalent. Automotive and equipment batteries are usually of the lead-acid type. This indicates that the dissimilar plates are made of two types of lead and the electrolyte is sulfuric acid. Wet-type batteries can also be nickel cadmium or nickel iron.

Most batteries are a series of cells enclosed in a common case. Each of these cells develops a potential (voltage) of 2.3 volts per cell when fully charged. Hence, a six-volt battery contains three cells and a 12-volt battery has six cells. The voltage output of a 12-volt battery is 13.8 volts when fully charged. Once a lead-acid battery has been placed in service, the addition of sulfuric acid is not necessary. The water portion of the electrolyte solution evaporates as the battery is charged and discharged. Lost water must be replaced. Deionized or distilled water should be used. Tap water contains impurities that shorten the life span of a battery if used to replace lost water. These minute particles become attached to the lead plates and do not allow the battery to rejuvenate itself fully when charged.

When batteries are placed on charge, remove the cell covers to allow the gas (hydrogen) caused by charging to escape and not to build excessive pressure in the battery. A battery on charge is as lethal as a small bomb if you ignite the gas. Do not smoke or cause electrical arcing near the battery. Do not breathe the gas and make sure that the area where a battery is being charged is well ventilated.

TABLE 7.2 IES RECOMMENDED EMERGENCY LIGHT LEVELS[a]

Hazard requiring visual detection	Slight		High	
NORMAL ACTIVITY LEVEL*	LOW	HIGH	LOW	HIGH
Areas	Conference rooms Reception rooms Exterior floodlighting Closets	Lobbies Corridors Concourse Restrooms, washrooms Telephone switchboard rooms Exterior entrance Exterior floodlighting	Elevators (freight) File rooms Mail rooms Offices Stairways Stockrooms Exterior entrance with stairs	Elevators Escalators Computer rooms Drafting rooms Offices Stairways Transformer vaults Engine rooms Electrical, mechanical, plumbing rooms
Footcandles	0.5	1.0	2.0	5.0
Dekalux	0.54	1.1	2.2	2.2

Minimum illumination for safety of personnel, absolute minimum at any time and at any location on any plane where safety is related to seeing conditions.

* Special conditions may require different levels of illumination. In some cases higher levels may be required as for example where security is a factor. In some other cases greatly reduced levels of illumination, including total darkness, may be necessary, specifically in situations involving manufacturing, handling, use, or processing of light-sensitive materials (notably in connection with photographic products). In these situations alternate methods of insuring safe operation must be relied upon.

EMERGENCY LIGHT LEVEL codes and standards vary widely throughout the country. Recommended minimum lighting levels of the Illuminating Engineering Soceity are being considered as a possible standard by ANSI and the Life Safety Code. These are minimum lighting levels recommended for safety of personnel.

[a] Reprinted from December, 1978 issue Electrical Construction and Maintenance, Copyright 1978 McGraw-Hill, Inc. All rights reserved.

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[7] *Electrolyte (ELECT-tro-LIGHT). A substance which dissociates (separates) into two or more ions when it is dissolved in water.*

The keys to prolonged life of a battery are to keep the electrolyte level above the cell plates, to keep the battery fully charged, and above all, to keep the terminals and top clean. When dirt and residue accumulate on the top of a battery, it forms a path for current to flow between the negative and positive posts. Take a multimeter, connect one lead to the proper post (it will cause up-scale deflection) and slowly slide the other lead across the top of the battery toward the other post. If the top is dirty, the meter will deflect more as you proceed across the top.

To clean the battery, use a stiff-bristled brush (not a wire brush) and remove the heavy material. Then wash with a solution of baking soda and water (four teaspoons of baking soda to one quart of water). This will remove the acid film from the top and neutralize corrosion on the battery terminals. Rinse with fresh water and dry the top with a dry, lintless cloth. Remove cell caps and wipe between them, then replace. At this time check to be sure that the battery terminals are clean and tight. If a battery is charged, but the terminals are loose, proper voltage and current cannot be delivered.

At one or other you may have given a battery a boost or may have seen it done. There is a correct procedure to follow to eliminate damage to electrical components and to prevent a battery explosion (Fig. 7.21).

To boost the battery of a disabled vehicle from that of another vehicle, follow this procedure. (Booster cables are available at auto-parts stores.)

First, park the auto with the 'live' battery close enough so the cables will reach between the batteries of the two autos. The cars can be parked close, but do not allow them to touch. If they touch, this can create a ground connection and create a dangerous situation. Now set each car's parking brake. Be sure that an automatic transmission is set in park, put a manual-shift transmission in neutral. Make sure your headlights, heater, and all other electrical accessories are off (you don't want to sap electricity away from your dead battery while you are trying to start your car). If the two batteries have vent caps, remove them. Then lay a cloth over the open holes. This will reduce the risk of explosion (relieves pressure within the battery).

Attach one end of the jumper cable to the positive terminal of the booster battery (**A**) (that's the good battery in the other car) and the other end to the positive terminal of your battery (**D**). The positive terminal is identified by a + sign, a red color, or a 'P' on the battery in your car. Each of the two booster cables has an alligator clip at each end. To attach, you simply squeeze the clip, place it over the terminal, then let it shut. Now attach one end of the remaining booster cable to the negative terminal of the booster battery (**B**). The negative terminal is marked with a − sign, a black color, or the letter 'N.' Attach the other end of the cable to a metal part on the engine of your car (**C**). Many mechanics simply attach it to the negative post of the battery. This is not recommended because a resulting arc could ignite hydrogen gas present at the battery surface and cause an explosion. Be sure the cables do not interfere with the fan blades or belts. The engine in the other car should be running, although it is not an absolute necessity.

Get in the disabled car and start the engine in a normal manner. After it starts, remove the booster cables. Removal is the exact reverse of installation. Remove the black cable attached to your engine, then remove it from the negative terminal of the booster battery. Then remove the remaining cable from the positive terminal of the 'dead' battery and then from the positive terminal of the booster battery. Remove the cloths from the fill-holes. Replace the vent caps and you are done. Have the battery and/or charging system of the car checked by a mechanic to correct any problems.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 546.

7.3A Why should a qualified electrician perform most of the necessary maintenance and repair of electrical equipment?

7.3B What is the purpose of a "kirk-key" system?

7.3C Why are battery-powered lighting units considered better than engine-driven power sources?

7.3D Why should the water lost from a lead-acid battery be replaced with deionized or distilled water?

7.33 High Voltage

7.330 Transmission

In general terms, high voltage is the voltage transmitted to the plant site by the utility company. The voltage level can vary, but 12,000 volts is quite common. After the power reaches the plant, it is transformed down to a useable voltage (460 to 480 volts) either through utility-owned or customer-owned transformers. The NEC (National Electrical Code) denotes high voltages as those over 600 volts.

Why have high voltage? Since current (amperes) varies inversely with voltage, a load of 500 amps on the low voltage side of the transformer would create a 20 amp load on the high voltage side of a 12,000 volts/480 volt transformer. Transmission lines would have to be enormous in order to carry the load if a lower voltage were used. Where high voltage cables terminate at a transformer or switch gear, certain conditions must be adhered to. If outdoor transformers are used that have high voltage wires exposed, an eight-foot (2.4 m) high fence is required to prevent accessibility by unqualified or unauthorized persons. Signs attached to the fence must indicate "High Voltage." Specifications for clearances, grounding, access, and enclosures vary with installations. Any modification or repair work must be completed by qualified people only.

7.331 Switch Gear

When we see the term 'switch gear,' it is usually associated with the equipment used in the interruption, transfer, or disconnecting of voltages over 600 volts. The enclosure is designed and manufactured to safely control high-voltage switching. Most distribution systems have a load-interrupting switch

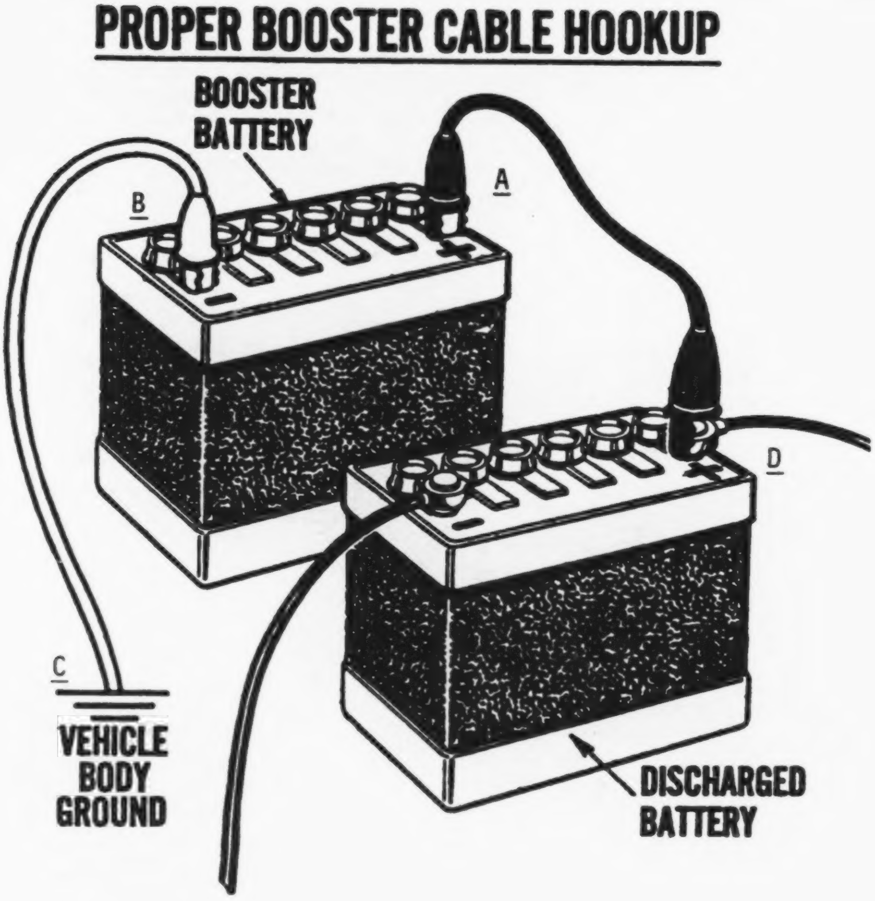

PROPER BOOSTER CABLE HOOKUP
BOOSTER BATTERY
A
B
C
D
VEHICLE BODY GROUND
DISCHARGED BATTERY

Fig. 7.21 Proper booster cable hookup

that is capable of disconnecting high voltage lines that are under load. Because of the arc that is caused in breaking the circuit, special 'arc shoes' (arc-suppressant devices) are used to ensure that the contact points are not pitted. A keyed lock system is used to prevent opening of the enclosure in the energized state.

Probably the best preventive maintenance that a treatment plant operator can provide for switch gear is to keep the exterior and its surroundings clean. If you encounter difficulties in the course of operating the switches, please obtain qualified help to do the inspection or repairs needed. Check with your particular manufacturer to determine what is needed and when this has to be done to keep your system functioning as designed. If your equipment is in a corrosive atmosphere, it may be necessary to remove it from service and epoxy paint the internal buses. All pivoting points should be lubricated with a lubricant specified by the manufacturer.

7.332 Power Distribution Transformers

If the high voltage transformers are owned by the utility, the inspection and maintenance is carried out by the utility. Any peculiar changes, smells, or noises should be reported to the utility. Where transformers are customer owned, a regular inspection program should be established.

Most transformers use an oil to insulate as well as to cool the windings. As heat is generated in the windings, it is transferred to the oil. The oil is then cooled by air passing the 'cooling fins' of the transformer. The primary requirements of the oil are:

1. High dielectric strength;
2. Freedom from inorganic acid, alkali, and sulfur to prevent injury to insulation and conductors;
3. Low viscosity to provide good heat transfer; and
4. Freedom from sludging under normal operation conditions.

The principal causes of deterioration of insulating oil are water and oxidation. The oil may be exposed to moisture through condensation of moist air due to 'breathing' of the transformer, especially when the transformer is not continuously in service. The moist air condenses on the surface of the oil and on the inside of the tank. Oxidation causes sludging. The amount of sludge formed in a given oil depends upon the temperature and the time of exposure of the oil to the air. Excessive operating temperatures may cause sludging of any transformer oil. Check with the manufacturer to determine how often the oil should be tested. Oil can be revitalized by a cleaning procedure that is accomplished at the transformer site.

Any symptoms such as unusual noises, high or low oil levels, oil leaks, or high operating temperatures should be investigated at once. If your transformer has a thermometer, it is of the alcohol type and should be replaced with that type only. A mercury-type thermometer could cause insulation failures by reason of proximity of a metallic substance, regardless of whether it is intact or broken.

The tank of every power transformer should be grounded to eliminate the possibility of obtaining static shocks from it or from being injured by accidental grounding of the winding to the case.

If repairs are indicated, use the expertise of a qualified person to ensure that the repairs are made safely as well as correctly. Your life and the lives of others may depend on the use of qualified people.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 546.

7.3E Why is electricity transmitted at high voltage?

7.3F What precautions must be taken if outdoor transformers have exposed high voltage wires?

7.3G What kind of maintenance should a treatment plant operator perform on switch gear?

7.3H What are the symptoms that a power distribution transformer may be in need of maintenance or repair?

7.4 GASOLINE ENGINES

7.40 Need to Maintain Gasoline Engines

In the wastewater treatment departments of all cities there is occasion to use gasoline-powered engines that drive pumps, generators, tractors, and vehicles. Although we all drive automobiles that are powered by internal combustion engines, are you aware of the fundamentals?

Very few operators actually do the repair of gasoline-powered engines. Although you may not be able to perform the duties of an engine mechanic, there are a number of steps you can take to ensure that your particular engine is well maintained.

At the end of this section you will have an adequate knowledge of how a gasoline engine operates in order to maintain it so as to provide many hours at optimum performance.

7.41 Four-cycle Engines (Air-Cooled)

7.410 Strokes in the Cycle

For the sake of simplification, this section will be confined to the air-cooled, single-cylinder engines. The four-cycle principles apply to liquid-cooled multi-cycled engines as well.

Air cooled engines' operating temperatures vary with load, air temperature and speed. Some of the advantages of an air-cooled engine are: (1) no complicated cooling system, (2) an engine of lighter weight than its liquid-cooled counterpart, and (3) comparatively easy repairs.

When we talk about 'compression stroke' and 'power stroke,' what are they? In a four-stroke-cycle engine, the crankshaft makes two complete revolutions to each power stroke of the piston as shown in Fig. 7.22.

First is the intake stroke (A), where the exhaust valve is closed and the intake valve open. The piston moves downward and draws a fuel-air mixture into the cylinder. Secondly, the intake valve closes and the piston moves upward on the compression stroke (B), compressing the fuel-air mixture between the top of the piston and the cylinder head. The spark occurs, igniting the mixture and the force of the expanded gases pushes the piston downward (power stroke C). The exhaust valve opens and, as the piston moves upward on the exhaust stroke (D), it forces the burnt gases out of the cylinder. Then the exhaust valve closes and the engine is ready for another cycle. Four strokes are required to complete the cycle.

7.411 Piston Displacement (Fig. 7.23)

What is it? Piston displacement is the space displaced by the piston in its up and down movement stroke. To compute

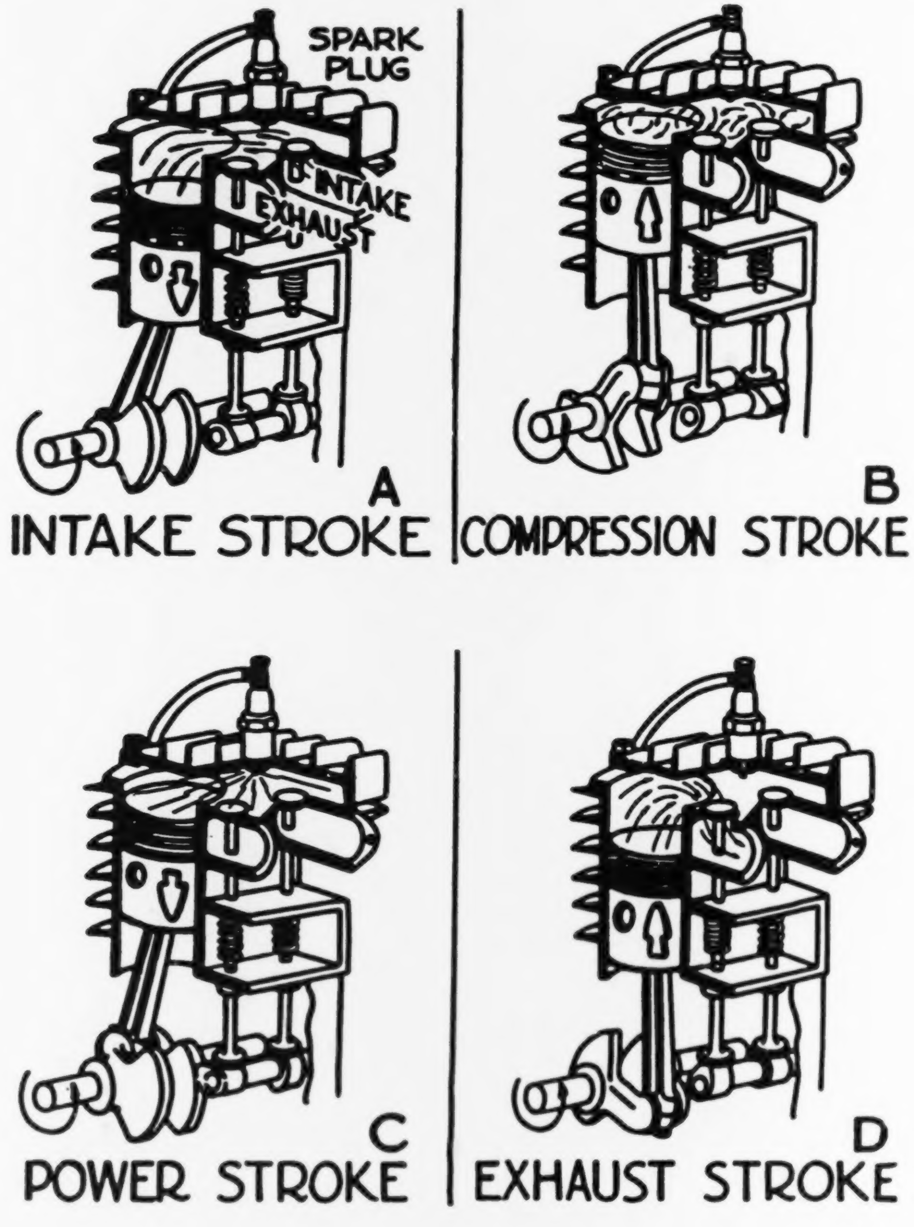

SPARK PLUG
INTAKE
EXHAUST
A
INTAKE STROKE
B
COMPRESSION STROKE
C
POWER STROKE
D
EXHAUST STROKE

Fig. 7.22 Four-stroke-cycle engine
(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

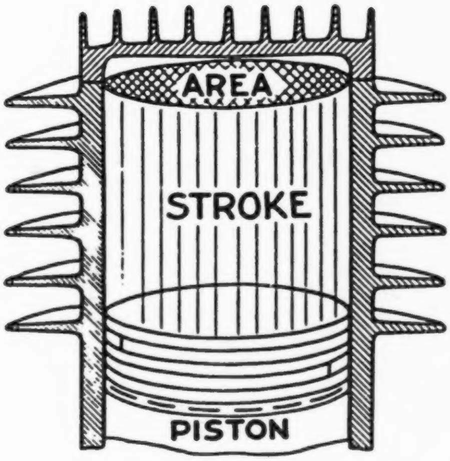

AREA
STROKE
PISTON

Fig. 7.23 Piston displacement
(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

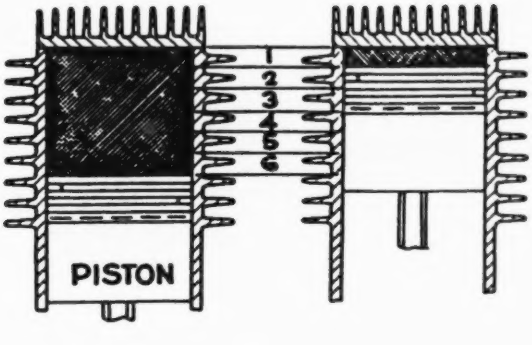

1
2
3
4
5
6
PISTON

Fig. 7.24 Compression ratio 1 to 6
(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

displacement, the following formula is used.

$$\text{Piston Displacement, cubic inches} = \frac{\pi}{4} \times (\text{Bore, in})^2 \times \text{Stroke Travel, in}$$

Calculate the piston displacement in cubic inches for an engine with a piston bore of two inches and a stroke travel of two inches.

$$\text{Piston Displacement, cubic inches} = \frac{3.1416}{4} \times (2 \text{ inches})^2 \times 2 \text{ inches}$$

$$= 6.28 \text{ cubic inches}$$

The horsepower of an engine is directly proportional to the volume of the piston displacement.

7.412 Compression Ratio (Fig. 7.24)

If an engine has a six to one compression ratio, it means that the volume remaining in the cylinder when the piston is at the top of the stroke is one-sixth as great as when it was at the bottom of the stroke.

Usually, the higher the compression ratio, the greater the efficiency. However, the compression ratio does not indicate the horsepower rating of an engine.

7.413 Valves and Timing

Valves (Fig. 7.25) play an important function in the operation of gasoline engines. Valves must open and close at the desired time. This is achieved by a "camshaft" that is geared to the "crankshaft." The gears are matched up so that the "timing marks" are directly in line. As the crankshaft revolves, so will the camshaft that actuates the valves in the desired manner.

The valves are exposed to varied conditions. When the fuel-air mixture ignites, the temperature in the cylinder can be in excess of 1,200 degrees F (650°C). The pressure exerted on the piston and also the valves may be as high as 500 psi (35 kg/sq cm). Valves and their seats are very important. Improper seating or operation will greatly affect the operation of the engine.

Two terms that you may have heard indicate valve problems: burnt valve and valve sticking. Valve and valve seat burning is usually caused by a buildup of carbon or fuel lead on the valve face or stem. These deposits hold the valve open allowing the hot flames of combustion to burn the valve face and seat. Valve sticking is caused by fuel lead, gum, or varnish that builds up on the valve stem and in the valve guide. When the exhaust valve does not close properly, the hot gases of combustion heat up the valve and valve guide. This causes the oil that lubricates the valve stem to oxidize into a varnish that causes the valve not to move freely. A sticky intake valve can be caused by using a fuel with high gum content.

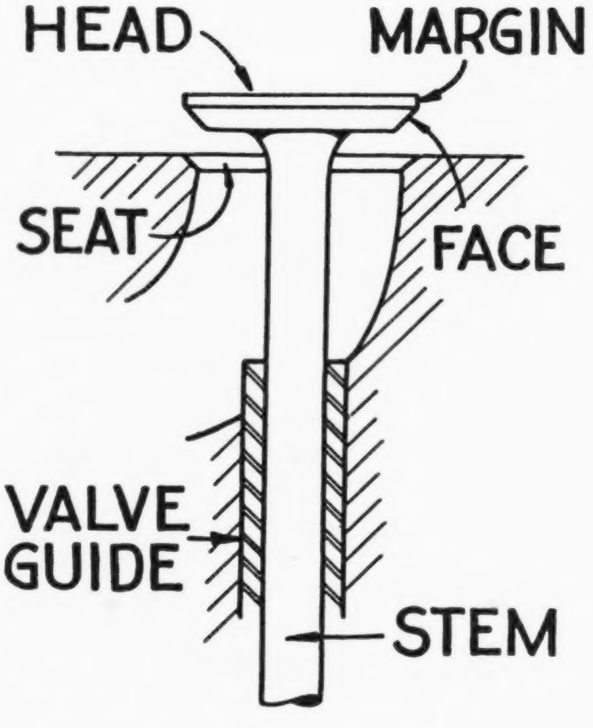


Fig. 7.25 Names of valve parts

(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

7.414 Carburetion (Fig. 7.26)

The purpose of a carburetor is to produce a mixture of fuel and air on which an engine will operate. Small-engine carburetors use atmospheric pressure, the principles of a venturi and the air foil (Fig. 7.26). They can be fed by a gravity fuel system, a vacuum, or a fuel pump. A venturi can be explained as a narrow space, similar to that of two buildings close together. The air current through this space is usually of high velocity. The venturi is placed in the carburetor to produce a volume of air flow in a specific manner.

As the piston in the cylinder moves downward with the intake valve open, it creates a low pressure area in the carburetor and venturi. The air pressure above the fuel in the bowl pushes the fuel down in the bowl and up through the nozzle discharge holes. At the same time, air rushes in through the venturi at a high velocity. The fuel that is forced through the nozzle mixes with the high volume of air coming through the venturi. This mixture of fuel and air is sucked into the cylinder and becomes the combustible mixture for firing the cylinder. The ideal combustion mixture is approximately 15 pounds of air to one pound of gasoline and is adjusted by the needle valve.

7.415 Ignition (Fig. 7.27)

In small four-cycle engines, a magneto is used to provide the electricity necessary to fire (spark) the plug in the cylinder head (Fig. 7.27). The ignition coil is mounted on a laminated steel yoke. The coil has a primary and secondary winding, like a transformer. As the fly wheel, which has a permanent magnet embedded in it, passes the yoke, a voltage is induced in the primary and secondary windings of the coil.

When the breaker points open, the collapsing primary circuit produces a peak voltage of 170 volts. This voltage is induced into the secondary winding producing a stepped-up voltage of 10,000 volts, which is more than ample to fire across the spark plug electrodes. The high secondary voltage dissipates rapidly; long enough to develop the necessary spark, but short enough to insure long electrode life.

The condenser, which is placed in parallel to the contact points, acts as a buffer. The condenser prevents the electricity from jumping the contact points causing arcing. When the points open, the condenser is charged by the low primary voltage, allowing the points to open without arc.

When discussing timing, the point of combustion comes when both the intake and exhaust valves are in the closed position. Therefore the timing of the valves, the position of the piston, and the instance of spark at the plug must be in sequence. If one or more are not, combustion does not take place.

7.416 Governing (Fig. 7.28)

The purpose of the governor is to provide a constant engine speed regardless of load. If the throttle is in a fixed position, the engine speed would go up or down as the load is decreased or increased. There are two common types of governors — air vane and counterweight.

The air vane governor (bottom of Fig. 7.28) is operated by the force of air provided by the fly wheel fins. The governor is connected to the carburetor throttled by means of a link. The force of air tends to close the throttle and slow the engine. Opposing this movement is the governor spring, which tries to open the throttle. The governor spring is connected to an adjustable control so that the tension can be adjusted by the operator. Increased tension causes greater engine speed; decreased tension lowers engine speed. The point where the spring pull equals the force of the air vane is called the "governed speed."

The governor that uses counterweights works similar to the air vane (top of Fig. 7.28). Instead of using air to oppose the governor spring, the centrifugal force of the counterweighs is used. The assembly is geared to the engine camshaft or crankshaft. As engine speed decreases with load, the centrifugal force on the counterweights is lessened. This allows the governor spring to open the throttle increasing engine speed. Conversely, if the engine load lessens and the engine starts to speed up, there will be greater centrifugal force. This increased force will work against the throttle spring and reduce engine speed. A properly operating governor will maintain governed engine speed within fairly close limits.

7.417 Maintenance

In order to have an engine that will provide you with many hours of trouble-free operation, it must be well cared for. *PLEASE REFER TO THE OWNER/OPERATOR MANUAL FOR YOUR PARTICULAR ENGINE.* Typical maintenance procedures are as follows:

1. Change engine oil regularly every 25 hours;
2. Clean carburetor air filter every 25 hours;
3. Blow dust and chaff from louvered engine vanes regularly;
4. Clean carburetor fuel filter/screen every 100 hours;
5. Lubricate generator and/or starter motor as recommended, every 100 hours;
6. Lubricate throttle linkage every 100 hours;
7. Clean, gap, or replace spark plug every 100 hours; and
8. Remove carbon deposits from top of piston and valves every 100 to 300 hours.

7.418 Starting Problems

Listed below are some items to check if you have problems starting a gasoline engine:

1. No fuel in tank, valve closed;
2. Carburetor not choked;
3. Water or dirt in fuel lines of carburetor;
4. Carburetor flooded;
5. Low compression;
6. Loose spark plug; and
7. No spark at plug.
    a. Dirty and improper/gapped plug,
    b. Broken or wet ignition cables,
    c. Breaker points not opening or closing, and
    d. Magneto grounded.

7.419 Running Problems

Check the following items if a gasoline engine does not run properly.

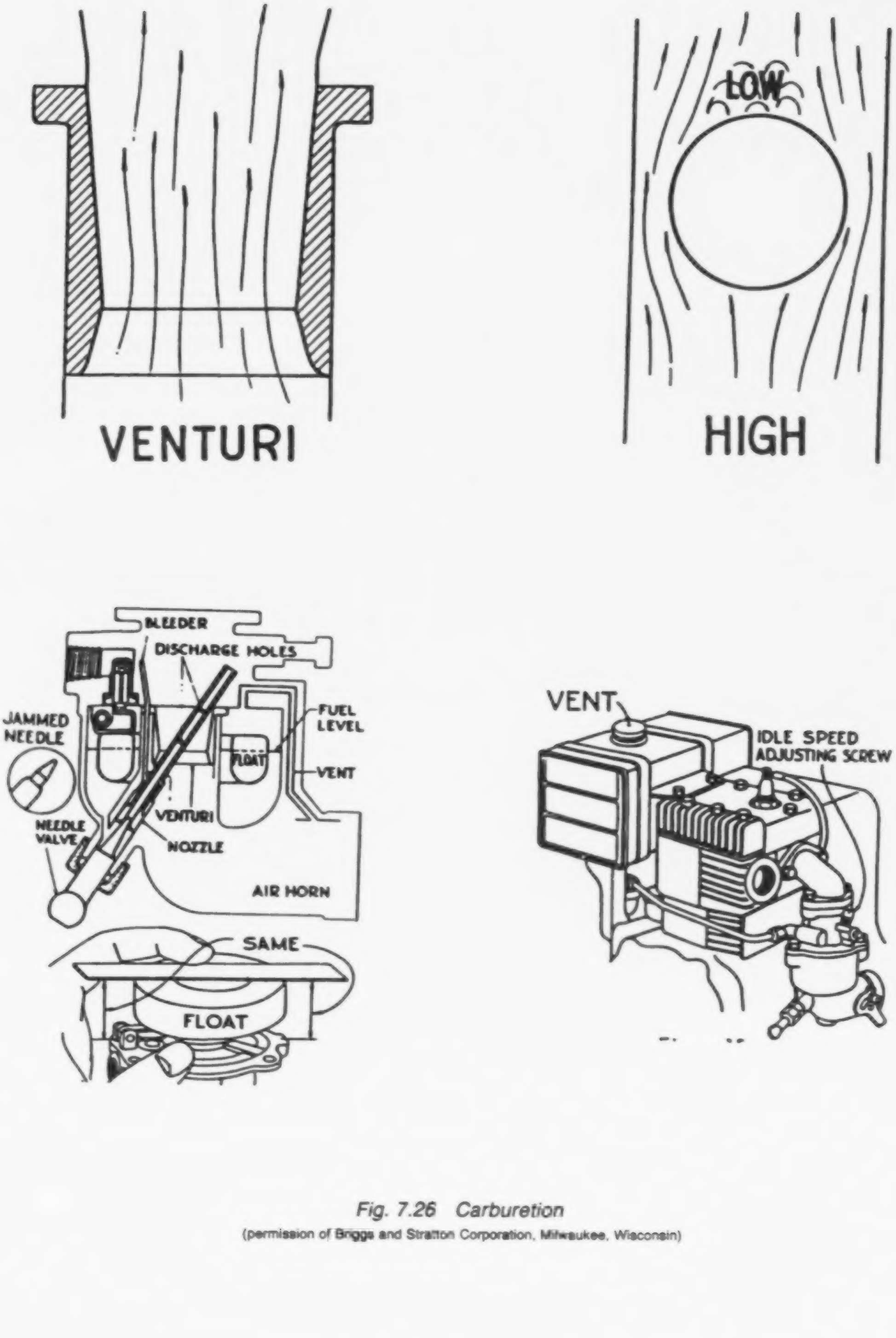

VENTURI
LOW
HIGH
BLEEDER
DISCHARGE HOLES
JAMMED NEEDLE
FUEL LEVEL
FLOAT
VENT
VENTURI
NEEDLE VALVE
NOZZLE
AIR HORN
SAME
FLOAT
VENT
IDLE SPEED ADJUSTING SCREW

Fig. 7.26 Carburetion

(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

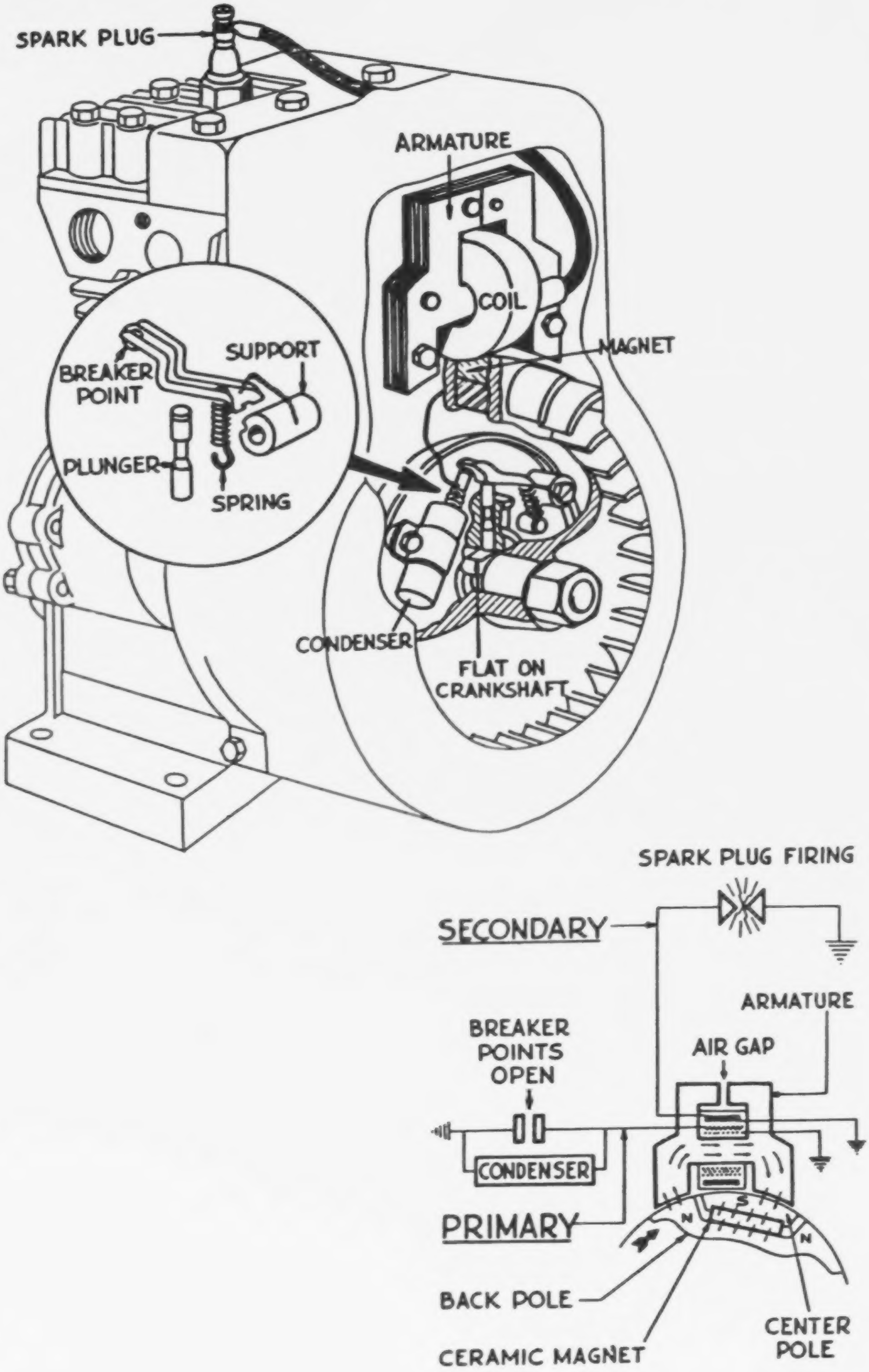

SPARK PLUG
ARMATURE
COIL
MAGNET
SUPPORT
BREAKER POINT
PLUNGER
SPRING
CONDENSER
FLAT ON CRANKSHAFT
SPARK PLUG FIRING
SECONDARY
ARMATURE
BREAKER POINTS OPEN
AIR GAP
CONDENSER
PRIMARY
N
S
N
BACK POLE
CERAMIC MAGNET
CENTER POLE

Fig. 7.27 Ignition

(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

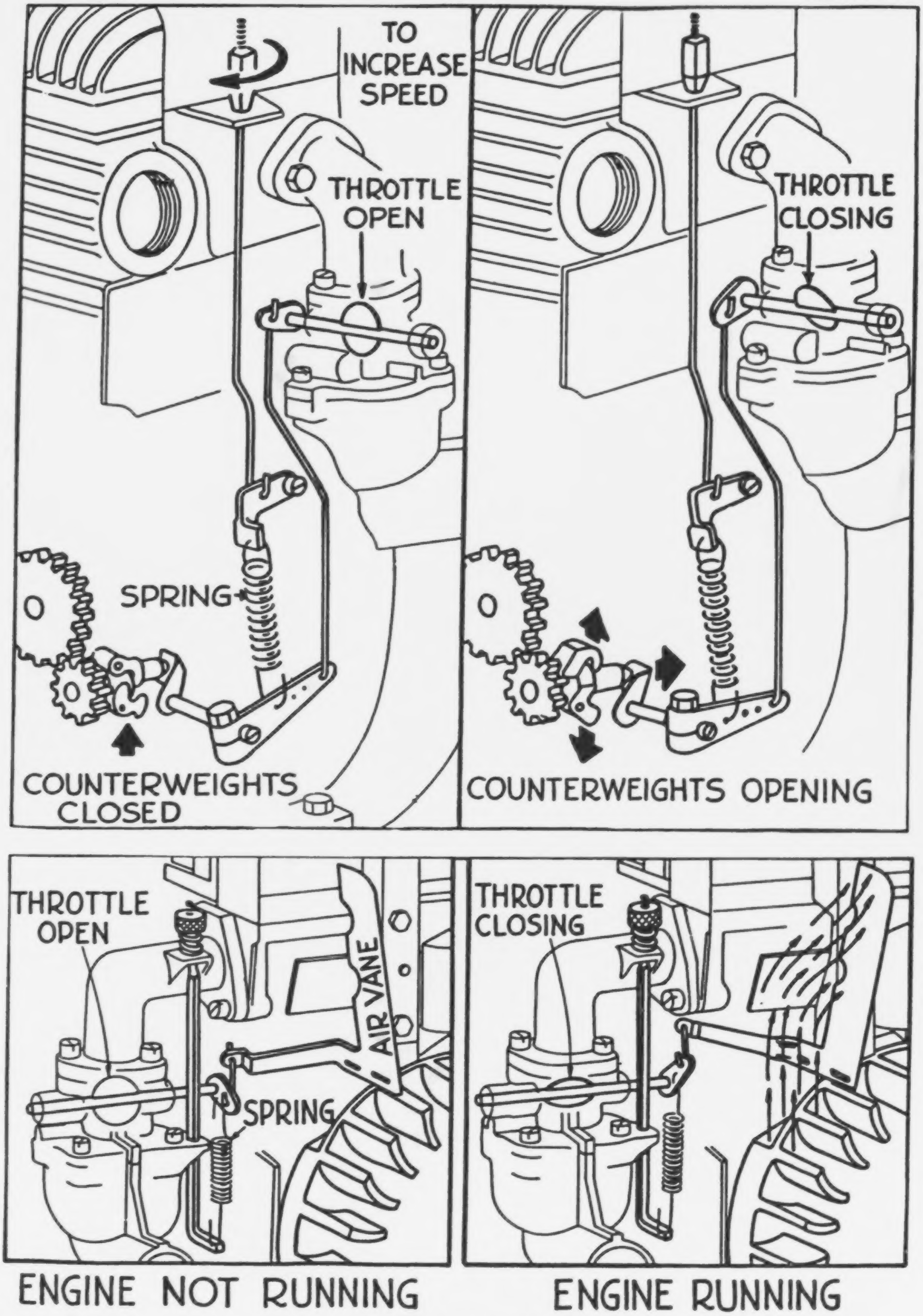

TO INCREASE SPEED
THROTTLE OPEN
SPRING
COUNTERWEIGHTS CLOSED
THROTTLE CLOSING
COUNTERWEIGHTS OPENING
THROTTLE OPEN
AIR VANE
SPRING
THROTTLE CLOSING
ENGINE NOT RUNNING
ENGINE RUNNING

Fig. 7.28 Governing

(permission of Briggs and Stratton Corporation, Milwaukee, Wisconsin)

1. Engine misses
   - a. Faulty spark plug/gapping
   - b. Weak ignition spark
   - c. Loose ignition cable
   - d. Worn breaker points
   - e. Water in fuel
   - f. Poor compressions
2. Engine surges
   - a. Carburetor flooding
   - b. Governor spring connected improperly
3. Engine stops
   - a. Fuel tank empty
   - b. Vapor lock
   - c. Tank air vent plugged
4. Engine overheats
   - a. Low crankcase oil
   - b. Ignition timing wrong
   - c. Engine overloaded
   - d. Restricted air circulation/high ambient temperature
   - e. Poor grade of gasoline
5. Engine knocks
   - a. Poor grades of gasoline
   - b. Engine under heavy load at low speed
   - c. Carbon deposits in cylinder head
   - d. Spark advanced too far
   - e. Loose connecting rod bearing
   - f. Worn or loose piston pin
6. Engine backfires through carburetor
   - a. Water or dirt in fuel
   - b. Cold engine
   - c. Poor grade of gasoline
   - d. Sticking inlet valves
   - e. Spark plug heat range too hot

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 546.

7.4A List the four strokes in a four-stroke-cycle engine.

7.4B Calculate the piston displacement in cubic inches for an engine with a piston bore of three inches and a stroke travel of four inches.

7.4C List two types of valve problems.

7.4D What is the purpose of a carburetor?

7.4E What is the purpose of a governor?

7.42 Large Four-cycle Engines (Water Cooled)

7.420 Differences Between Small and Large Engines

The previous section discussed the fundamentals of small, four-cycle engines. Those same fundamentals apply to the large, four-cycle engines, however, there are some differences:

1. Multi cylinders,
2. Water cooled engine block,
3. Engine lubrication,
4. Ignition systems, and
5. Valves (Inhead/Inblock).

7.421 Multi Cylinders

In an engine with more than one cylinder, it is important to sequence the detonation of combustion so as to give a smooth running (balanced operating) engine. Geared to the crankshaft, the camshaft must operate the inlet and exhaust valves of each cylinder. Combustion can be taking place in one or more cylinders, compression stroke in others, and exhaust and intake strokes in the remaining. Timing of valve operation relative to the position of the piston is therefore quite similar.

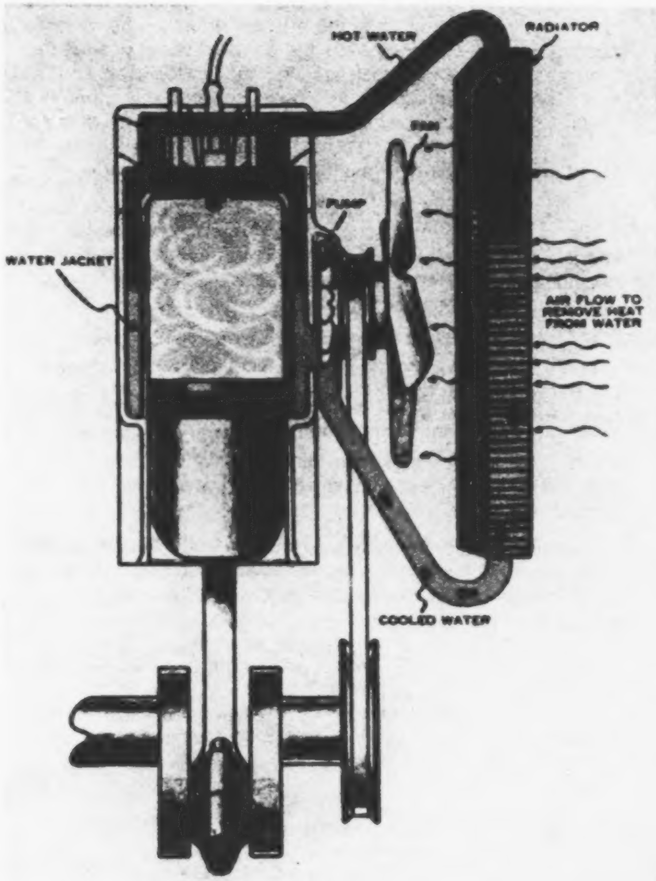
7.422 Water Cooled (Fig. 7.29)

In an air-cooled engine, the heat generated by combustion was dissipated by the air circulating past the louvered cylinder block. With a water-cooled system, the same effect is achieved by using water. Each cylinder is surrounded with a water jacket through which coolant circulates. This is accomplished by a water pump that is belt-driven from the crankshaft. The heat transfers from the cylinder wall to the water which, in turn, is pumped back to the radiator where the heat is dissipated. A fan mounted on the same shaft as the water pump ensures that a large volume of air is blown across the radiator coils to facilitate rapid disbursement of heat. The cooled water is then pumped back into the engine.

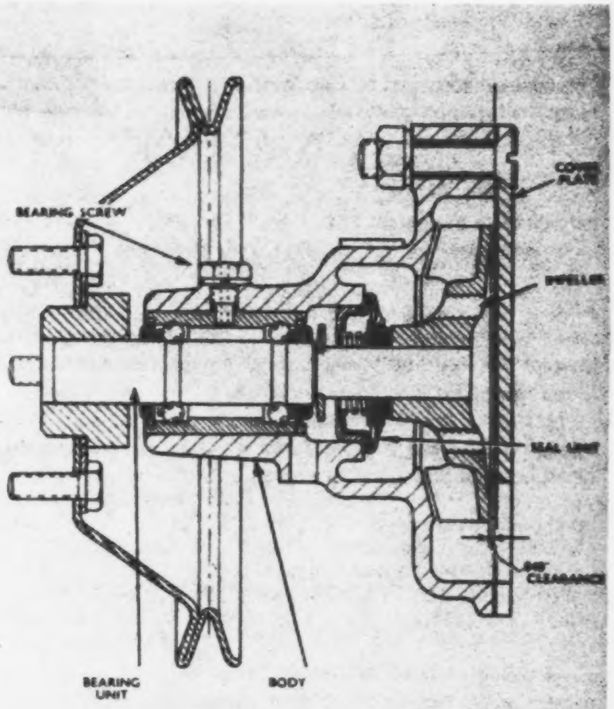
Internal combustion engines operate more efficiently when their temperature is maintained within narrow limits. This objective is achieved with the insertion of a thermostat in the cooling system which is called a "temperature actuated valve." When the engine is cold, the thermostat remains closed not allowing the water to circulate back to the radiator. As the engine temperature increases to normal operating temperature, the thermostat opens.

The radiator cap provides a function other than preventing coolant from splashing out the filler opening. The cap is designed to seal the cooling system so that it operates under pressure. This improves cooling efficiency and prevents evaporation of coolant. The boiling point of water is 212 degrees F (100°C). However, for every pound of pressure applied to the system, the boiling point rises 3.25 degrees F (1.8°C). If your cooling system had a 15 psi (1 kg/sq cm) radiator cap and used water for coolant, it would have a boiling point near 260 degrees F (127°C).

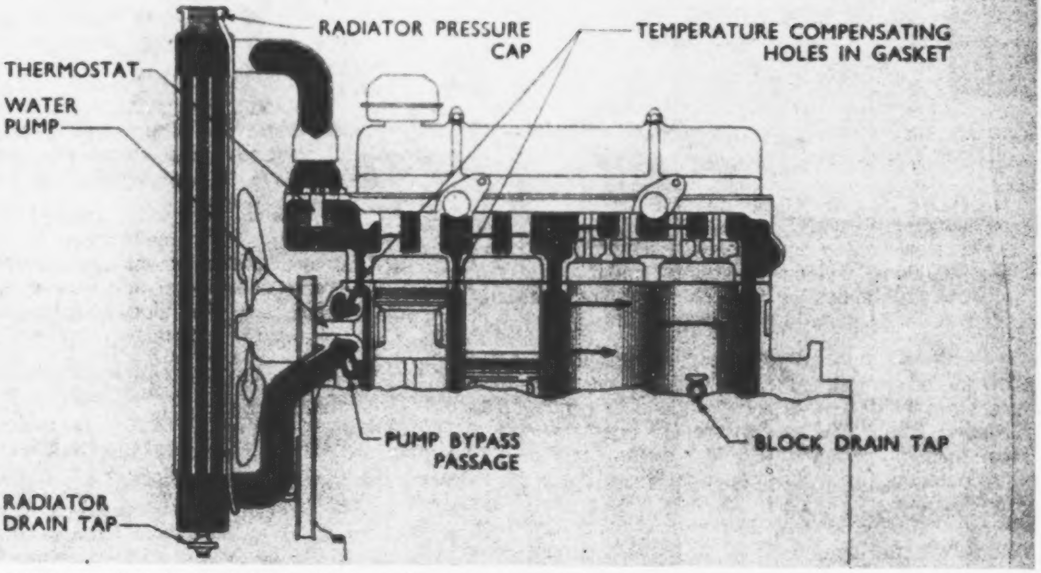
The use of coolant/anti-freeze provides protection against the radiator coolant freezing and rupturing the system and also provides better heat transfer and heat dissipation characteristics than water. Most of the name-brand coolants have rust inhibitors. Rust buildup in the cooling system does not allow


HOT WATER
RADIATOR
FAN
PUMP
WATER JACKET
AIR FLOW TO REMOVE HEAT FROM WATER
COOLED WATER

Engine temperatures are regulated by transferring excess heat to surrounding air.


BEARING SCREW
COVER PLATE
IMPELLER
SEAL UNIT
AIR CLEARANCE
BEARING UNIT
BODY

Shaft ball bearings are sealed at each end to keep lubricant in and water out of bearings. A spring-loaded seal (in color) is used to avoid water leakage around pump shaft. Note clearance between impeller and cover plate.


RADIATOR PRESSURE CAP
TEMPERATURE COMPENSATING HOLES IN GASKET
THERMOSTAT
WATER PUMP
PUMP BYPASS PASSAGE
BLOCK DRAIN TAP
RADIATOR DRAIN TAP

With water jackets entirely around each cylinder and valve, there is a great amount of area exposed to the circulating coolant.

Fig. 7.29 Water cooling system

(Source Automotive Encyclopedia, permission of the Goodheart-Willcox Co., Inc.)

good heat transfer and the sloughing of rust scale can block narrow passages.

7.423 Engine Lubrication (Fig. 7.30)

A properly lubricated engine will ensure minimal wear of the moveable internal parts. The large four-cycle engines usually have a pressurized lubricating oil system. This system consists of an oil pump, a gear driven from the camshaft, an oil filter, and a number of ports and tubes within the engine that direct the lubricant to the proper places.

The oil pump generally is of two types, rotary or gear type. The pump suction is at the oil sump, oil is drawn through a screen and then pumped to the oil filter and through the engine. Fig. 7.30 will give you an insight on how the oil pump works. An oil filter serves to remove particles from the oil that may be abrasive or clog the lubricating parts of the engine. The oil and filter must be changed as specified by the manufacturer.

Engine oil is available in different viscosities (flow characteristics) and service ratings. The number designated on the container indicates its viscosity, as assigned by the Society of Automotive Engineers (SAE). An SAE 10 oil may be recommended for cold weather operation and an SAE 30 for warm weather. The designation "W" as 10 W indicates that the oil will stay fluid over a wider range of temperatures. Thus a 10 W oil can be used under more severe conditions than SAE 10 oil.

The service ratings are as follows:

MS, MM, and ML for gasoline engines;
DG and DS for diesel engines;
MS severe duty — heavy load-high speed;
MM medium service — moderate load and speed;
ML light service — light load, moderate speed, and short operating time for engine;
DS severe conditions — high and low temperatures, changing engine load and where diesel fuel is of high sulfur content; and
DG moderate service — typical for most farm tractors and trucking conditions.

When you change engine oil, check the specifications or owner's manual to ensure the proper lubricant is used.

7.424 Ignition Systems — Battery and Magneto

BATTERY SYSTEM (Fig. 7.31)

The ignition system consists of the battery, ignition coil, distributor, condenser, ignition switch, spark plugs, and related high and low tension wiring.

The purpose of the ignition coil is the same as that mentioned in Section 7.415, "Ignition." The coil steps up the six or twelve volts from the battery to a high tension voltage near 20,000 volts that is required to jump the spark plug gap and initiate combustion. The condenser reduces arcing at the breaker points and insured long contact life.

One of the major differences between single- and multicylindered engines is the distribution of high tension electrical current to the respective cylinders. This must be accomplished when a given cylinder is near the top of the compression stroke. The ignition distributor (Fig. 7.32) with its contact points is designed to make and break the primary ignition circuit and distribute high tension current to the proper spark plug. This distributor is usually driven by the camshaft that actuates the valves at one-half crankshaft speed for four-cycle engines, since the engine fires on every other revolution.

The breaker points sit under the rotor that selectively feeds high tension voltage through the cap to the plug wires and covers the spark advance mechanism. The breaker points are actuated by a cam. Usually there is one lobe on the cam for each cylinder of the engine. As the cam rotates, it passes the breaker lever rubbing block causing the points to open and close. When the breaker points open, the collapsing primary circuit of the ignition coil induces a voltage into the secondary. The rotor connects the high tension voltage through the cap to the appropriate cylinder.

In order to achieve efficient operation of an internal combustion engine throughout its operating range, it is essential that spark occurs at the correct instant. That instant will vary with engine speed and load. The method used to advance or retard the spark is a "centrifugal" and "engine vacuum" advance mechanism.

When the engine is idling, ignition takes place just before the piston reaches the top of the compression stroke. At high engine speeds, the time interval for the fuel mixture to ignite and expand is shorter. In order to obtain maximum power at high speeds, the ignition must take place slightly earlier in the engine cycle. This is accomplished by the centrifugal advance mechanism.

Vacuum spark advance is also used to assist the centrifugal mechanism. A lever connected to the advance unit is actuated by a spring-loaded diaphragm that is sensitive to vacuum changes in the carburetor. As the speed of an engine increases, a greater vacuum is produced in the carburetor. The increased vacuum pulls on the diaphragm causing the spark advance mechanism to rotate. The cylinder then fires slightly earlier in the cycle. When the engine speed is lowered, less vacuum is produced and the mechanism retards the time of ignition.

MAGNETO SYSTEM (Fig. 7.33)

A magneto is a self-contained device that generates and distributes electricity needed to ignite the fuel mixture in the combustion chamber. The magneto develops a low voltage, steps it up to a high tension voltage, and distributes it at the proper time. All of this is accomplished without the use of a battery or ignition coil. (Because no battery is needed and the voltage generated by the magneto increases with engine speed, it is a desirable alternative to the battery-powered ignition system.)

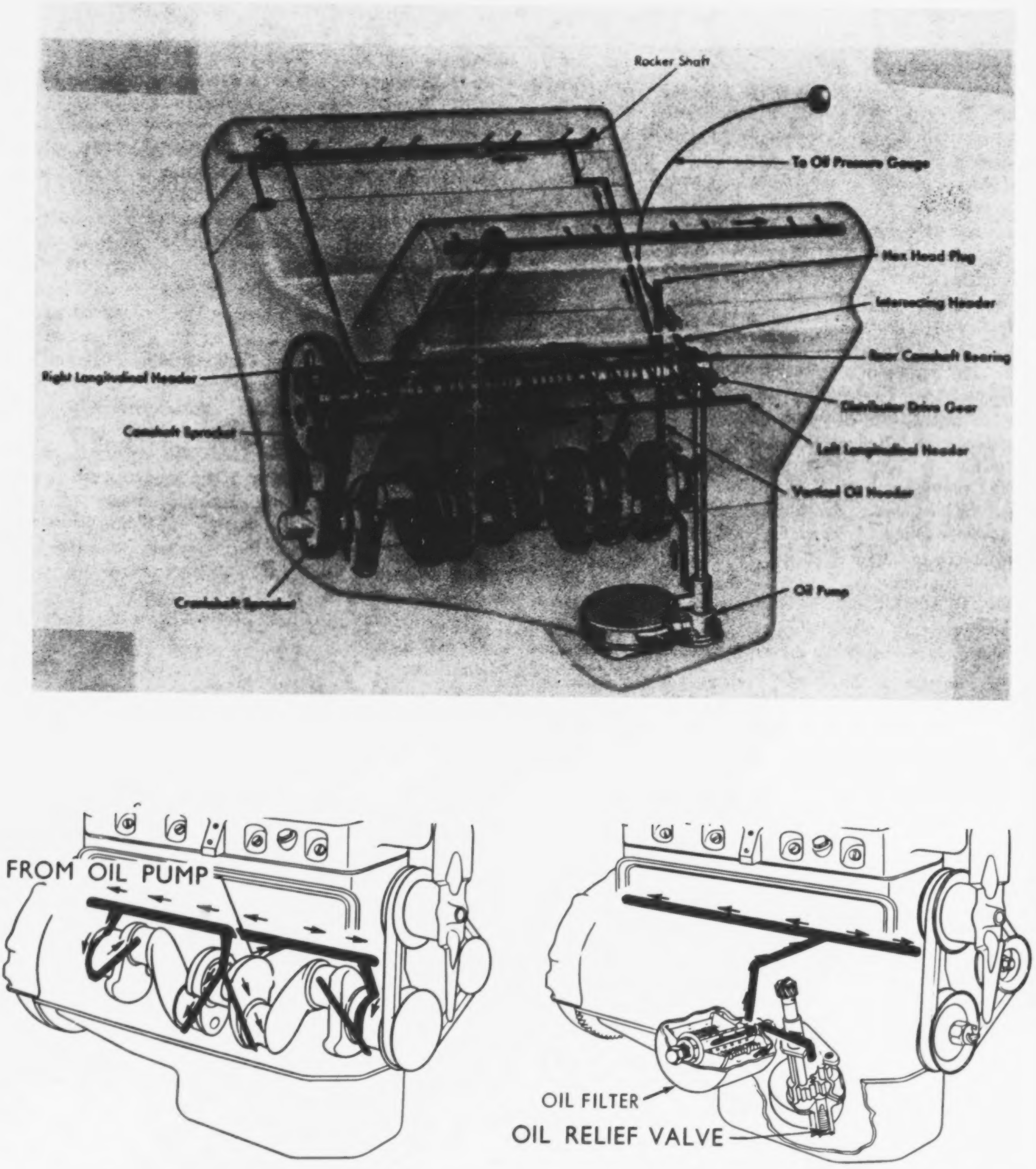
The magneto distributes electricity in a manner similar to the distributor. The magneto has a cap, rotor, breaker points, and condenser. (See magneto fundamentals in Section 7.415, "Ignition.")

In general, magnetos are used on engines that operate in a relatively small range of speed. This is because spark advance is controlled by centrifugal counterweights that shift the degree of angle at which the points open and close. Since the range of control is limited (not so in distributors with vacuum advance), the engine speed range must also be limited.

7.425 Valves

The valves of large four-cycle engines are either in the block or cylinder head. By far, a greater number of engines are of the overhead valve type. Some of the advantages to overhead valves are:

1. Easier to work on because head is removable,
2. Quieter valve operation,


Rocker Shaft
To Oil Pressure Gauge
Hex Head Plug
Intersecting Header
Rear Camshaft Bearing
Right Longitudinal Header
Distributor Drive Gear
Camshaft Sprocket
Left Longitudinal Header
Vertical Oil Header
Oil Pump
Crankshaft Sprocket
FROM OIL PUMP
OIL FILTER
OIL RELIEF VALVE

Oil passages drilled in crankshaft conduct oil from main bearings to connecting rods.

In this engine application, oil goes through a filter placed between oil pump and oil gallery.

Fig. 7.30 Engine lubrication

(Source Automotive Encyclopedia, permission of the Goodheart-Willcox Co., Inc.)

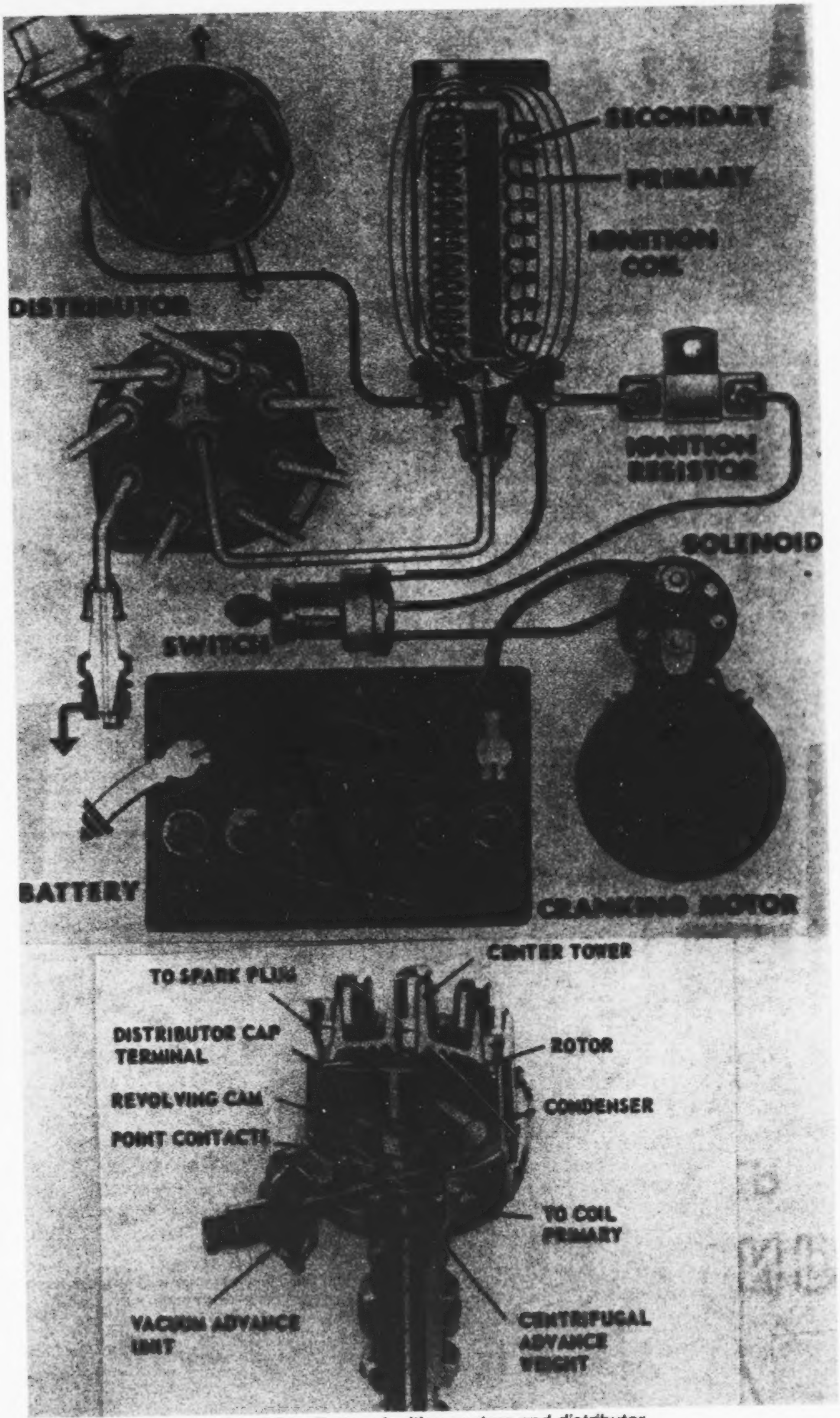

SECONDARY
PRIMARY
IGNITION COIL
DISTRIBUTOR
IGNITION RESISTOR
SOLENOID
SWITCH
BATTERY
CRANKING MOTOR
CENTER TOWER
TO SPARK PLUG
DISTRIBUTOR CAP TERMINAL
ROTOR
REVOLVING CAM
CONDENSER
POINT CONTACTS
TO COIL PRIMARY
VACUUM ADVANCE UNIT
CENTRIFUGAL ADVANCE WEIGHT

Fig. 7.31 Battery ignition system and distributor

(Source Automotive Encyclopedia, permission of the Goodheart-Willcox Co., Inc.)

Fig. 7.32 Ignition distributor

(Source Automotive Encyclopedia, permission of the Goodheart-Willcox Co., Inc.)

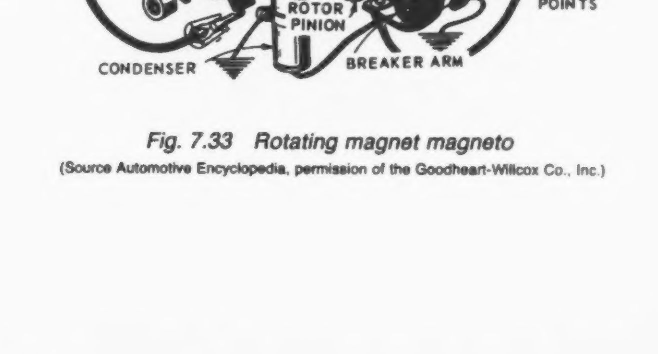

HIGH TENSION
LEAD ROD
COIL
IMPULSE
COUPLING
DISTRIBUTOR
GEAR
SPARK
PLUGS
DISTRIBUTOR
ROTOR
MAGNETIC
ROTOR
FRAME
LAMINATIONS
BREAKER
POINTS
ROTOR
PINION
CONDENSER
BREAKER ARM

Fig. 7.33 Rotating magnet magneto

(Source Automotive Encyclopedia, permission of the Goodheart-Willcox Co., Inc.)

3. Better valve response, and
4. Ease of valve adjustment.

7.426 Maintenance and Troubleshooting

Regularly scheduled maintenance is a must. Refer to your owner's manual for specific recommendations.

1. Change engine oil	100/150 hours
2. Clean air filter/replace	100/150 hours
3. Change oil filter	100/150 hours
4. Lubricate starter motor and generator	100/150 hours
5. Inspect battery water, terminals	100/150 hours
6. Replace fuel filter or clean	500 hours
7. Inspect drive belts and belt tension	500 hours
8. Inspect radiator hoses	500 hours
9. Blow dust and debris from radiator core	500 hours
10. Backflush coolant system and add new coolant	2 years

The items listed are in addition to those listed in the preceding sections.

STARTING PROBLEMS

1. Poor battery connection/engine will not crank
2. Distributor cap damp
3. Break in ignition wiring
4. Engine valves out of time/spark advance

ENGINE STOPS

1. Plugged fuel filter/screen
2. No ignition voltage

ENGINE OVERHEATS

1. Low radiator coolant
2. Radiator core partially blocked
3. Faulty water pump
4. Sticking thermostat

7.43 Small Two-cycle Engines (Air Cooled) (Fig. 7.34)

7.430 How Two-cycle Engines Work

The two-cycle engine provides power with each revolution of the crankshaft. In order to do this, the piston takes over some of the valve functions along with "ports" in the cylinders. The key thing to remember about most small two-cycle engines is that the fuel mixture (oil and gasoline) provides lubrication for the moveable parts in the crankcase as well as an air-fuel mixture for combustion.

The fuel-air mixture from the carburetor enters the engine crankcase through a leaf- or reed-type check valve. At the bottom of the stroke, the fuel mixture is drawn up the cylinder port to the top of the combustion chamber. The upward movement of the piston creates a vacuum and draws the fuel from the carburetor into the crankcase. As the cylinder fires and is driven to the bottom of the stroke, the crankcase becomes pressurized. This forces the fuel-air mixture up the cylinder port and expels exhaust gases through the exhaust port. In the process, the cylinder is recharged for the compression stroke. Timing, carburetion, and ignition are all similar to four-cycle engines.

Probably the most important item in regard to the two-cycle engine is the proper fuel mixture — usually 50 parts gasoline to one part oil. Most manufacturers recommend using an SAE 30 oil designed for two-cycle engines. If the fuel mixture contains too much oil, you'll have poor carburetion, poor engine performance, excessive smoke out the exhaust, and incomplete burning of the mixture. On the other hand, if the mixture has too little oil, poor lubrication of crankshaft, connecting rod bearings, and piston cylinder wall takes place. This can cause premature bearing failure and scored cylinder walls. The engine will run hot and may *SEIZE UP.*[8] *THAT'S HOW IMPORTANT THE FUEL MIXTURE IS.*

A few advantages of the small two-cycle engine are:

1. Cheaper to manufacture,
2. Fewer moving parts,
3. No engine oil changes (decreased maintenance), and
4. Proper engine lubrication is not relative to the position of the engine. (This feature is sometimes desirable in small pump and blower use. A four-cycle engine must be kept somewhat level to ensure proper internal engine lubrication.)

7.431 Maintenance and Troubleshooting

The maintenance schedule of a two-cycle engine is similar to that of the four-cycle engine, with the exception that the crankcase does not use an "oil bath." Therefore, proper fuel mixture is a must. Problems associated with starting and operating are similar for both two- and four-cycle engines.

Please make special note of the information in regard to fuel mixture contained in Section 7.430.

7.44 How to Start a Gasoline Engine

Because of the wide variety of uses for gasoline-powered engines, no one starting sequence will apply to all engines. In general, gasoline engines can be divided into two groups. In the first group are small engines with magneto ignition and recoil start. Larger engines with battery-powered ignition and electric start are in the second group.

7.440 Small Engines

The procedure for starting small engines is as follows:

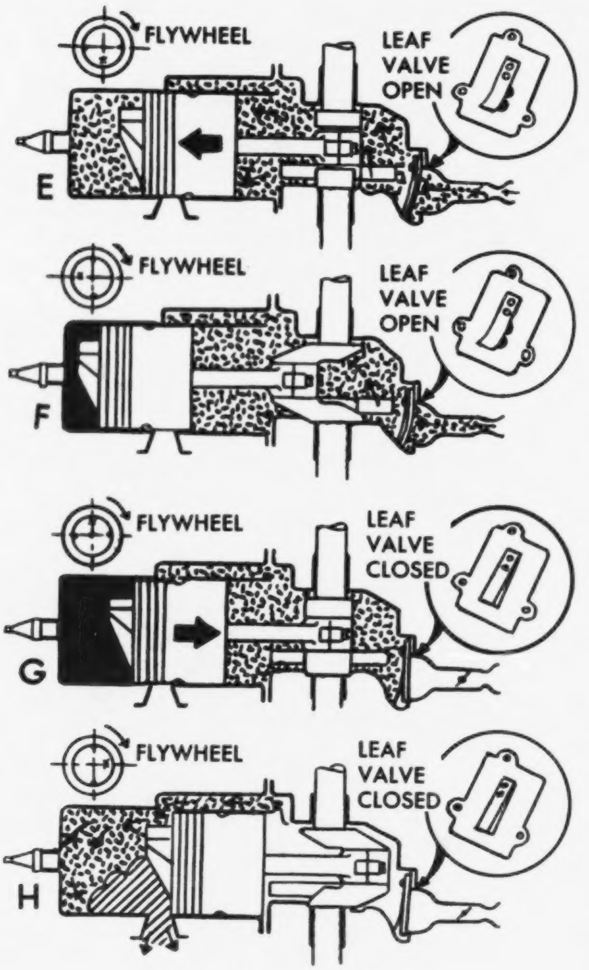
1. Check fuel tank for adequate fuel;
2. Ensure fuel shut-off valve from the tank to the carburetor is open;
3. Disengage ignition ground ("kill" switch or mechanism that grounds the spark plug);
4. Check crankcase lubricating oil;
5. Set throttle to start position or ¾ full throttle;
6. Set choke lever or pull out choke on carburetor;
7. Pull recoil starter twice;
8. If engine has started, push choke to "off"; and
9. If engine does not start after two pulls, disengage the choke and try three or four more times.

If repeated efforts at starting have been unsuccessful, remove the high tension voltage wire from the spark. Hold the

---

[8] *Seize up. Seize up occurs when an engine overheats and a component expands to the point where the engine will not run. Also called "freezing."*

TWO CYCLE ENGINE



Provides power impulse for each two strokes of piston; each revolution of crankshaft.

E. Mixture of fuel and air from carburetor enters engine crankcase through check-valve. When piston is at bottom of cylinder, port is uncovered. As preceding movement of piston has compressed gas in crankcase, mixture flows into cylinder. Further compression in cylinder starts as soon as piston reverses and covers ports.

F. At the same time compression is occurring in cylinder, movement of piston has created vacuum in crankcase which draws fresh charge of mixture from carburetor into crankcase. Charge is fired at limit of piston movement.

G. As expansion of burning charge forces piston downward, check-valve in crankcase closes and mixture in crankcase is compressed.

H. As piston uncovers ports at bottom of stroke, compressed mixture from crankcase enters cylinder and is deflected by baffle on piston head into outer end of cylinder. Incoming fresh mixture assists in pushing spent gas out of cylinder.

░ *FUEL AND AIR MIXTURE*

■ *BURNING FUEL MIXTURE*

▨ *EXHAUST OF SPENT FUEL*

Sequence of operation of two cycle engine.

GM's two cycle diesel: A–With piston at bottom of stroke, intake ports are uncovered and blower forces air into cylinder. B–Upward movement of piston closes intake ports and compresses air, thereby raising its temperature. C–At top of piston stroke, fuel is injected and ignited by high temperature of compressed air. D–Expanding gases force piston down on power stroke. Exhaust valve is opened and burned gases are forced out by compressed air.

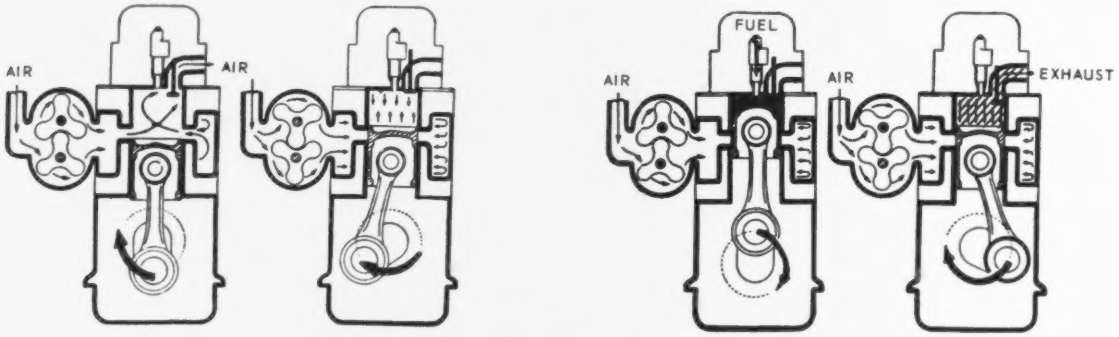


Fig. 7.34 Two-cycle engine

(Source Automotive Encyclopedia, permission of the Goodheart-Willcox Co., Inc.)

end of the wire (grasp the insulated portion, *NOT* the connector) ⅛ inch (3 mm) from the spark plug. Pull the recoil starter. You should see a small blue spark. This will indicate that the points are opening and closing and providing ignition voltage.

The next step is to remove the spark plug from the cylinder head (use a $^{13}/_{16}$ inch (20.6 mm) deep socket). Check for a carbon buildup on the electrode. A piece of carbon may have lodged between the center electrode and the side electrode. Also check to see if the plug is wet with fuel or oil. This could indicate that you have flooded the cylinder with fuel by having the choke on too long. If there is oil residue, it could indicate worn piston rings.

Replace the spark plug with a new one if in doubt. If you must use the one you have, clean it by buffing with a wire brush. Check the "gap" between the center electrode and side electrode; it should be approximately .030 inch (30 thousands of an inch or 0.76 mm).

Try starting the engine as previously described. If the engine does not sputter or pop, close the fuel shut-off valve, remove fuel sedimentation bowl and clean. Open fuel valve. Catch a small amount of fuel in the palm of your hand and examine the fuel for grit or water. If everything looks okay, replace sediment bowl and open fuel valve.

Try to start the engine. If you still cannot achieve ignition, you may have other problems that will require further checking by a small-engine mechanic. Do not feel disgruntled, you have checked for the most common problems.

7.441 Large Engines

The procedure for starting large engines is as follows:

1. Check fuel tank for fuel;
2. Check crankcase for oil;
3. Check radiator for coolant (if water cooled);
4. Set throttle to ½ full position;
5. Pull out choke;
6. Turn on ignition switch and press start button;
7. After four or five engine revolutions, push in the choke; and
8. Engine should start.

After repeated tries, further investigation by a mechanic may be needed.

NOTE: Do not crank engine with the starter motor for more than one minute initially. Wait two minutes and try again for 45 seconds. Wait two minutes and try again for 30 seconds. After three trys, let starter motor cool for 5 minutes before trying again. This will avoid starter motor damage.

Preliminary checks for a large engine that won't start are similar to procedures for small engines.

Remove spark plug wires. Test each one by holding it ⅛ inch (3 mm) from the spark plug or ground, and turn engine over with the starter. You should see a small blue spark. If you have no spark, the points are not opening or high tension voltage is not present from the ignition coil. Check further as needed.

If spark is present, inspect spark plugs. Clean or replace if needed.

After checking the ignition system, make sure fuel is present at the carburetor. Remove the fuel line at the carburetor and direct it away from you and the engine. Engage starter motor for two revolutions. Fuel should spurt from the line if the fuel pump is working satisfactorily. Replace fuel line and wipe away any fuel that may be present on the engine.

With fuel and ignition voltage present, it should start. Repeat start procedure. If you still cannot start the engine, call on your mechanic to look for the problem.

NOTE: Some engines have a low oil pressure switch that must be manually held in until sufficient oil pressure is present.

Do not use a starting fluid on gasoline engines unless it is a *LAST RESORT* effort to get a critical piece of equipment running. Hard-starting engines should be inspected and repaired by a reliable mechanic.

After an engine has been started, give it an opportunity to warm up before applying the load. Follow manufacturer's recommendations for the starting procedure since there is some variation between different makes of engines.

QUESTIONS

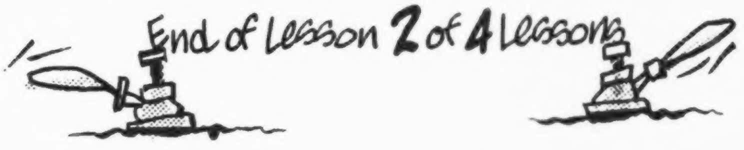
Write your answers in a notebook and then compare your answers with those on page 546.

7.4F How is heat removed from the cylinders in a water-cooled engine?

7.4G What is a magneto?

7.4H How are the moveable parts in the crankcase of a small air-cooled two-cycle engine lubricated?

7.4I What happens if the fuel mixture contains (1) too much oil or (2) too little oil?


End of Lesson 2 of 4 Lessons

Please answer the discussion and review questions before continuing with Lesson 3.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 4 Lessons)

Chapter 7. MAINTENANCE

Write your answers to these questions in your notebook before continuing. The question numbering continues from Lesson 1.

7. Why should a wastewater treatment plant have standby power?
8. How would you determine the capacity of standby generation equipment?
9. Why should you not smoke or allow electrical arcing near a battery being recharged?
10. What causes (1) valve and valve seat burning, and (2) valve sticking?
11. What factors could cause gasoline engine starting problems?
12. Why is rust a problem in water-cooled systems?

CHAPTER 7. MAINTENANCE

(Lesson 3 of 4 Lessons)

7.5 DIESEL ENGINES

7.50 How Diesel Engines Work (Fig. 7.35)

Diesel engines are similar to gasoline engines and are either two or four cycle. They can be air or water cooled. In general the diesel engine is of heavier construction to withstand the higher pressures resulting from higher compression ratios.

The diesel does not use spark plugs, but instead relies on heat generated by air compressed in the cylinder (1,000 degrees F or 540°C) to ignite the fuel mixture. The fuel is a petroleum product that is heavier than gasoline and with a higher flash point. Gasoline cannot be used in a diesel because it would start to burn from the heat generated by compression before the piston reached the top of the stroke.

A diesel has no carburetor. The fuel is sprayed (injected) into the cylinder while the cylinder is compressing air. The heat of compression ignites the fuel-air mixture and burns, producing power similar to a gasoline engine. The introduction of fuel into the cylinder must be "timed" in the same manner as spark to the plug in a gasoline engine. Fuel is pumped by a pumping device that is geared to the crankshaft.

Diesel fuel, unlike gasoline, does not vaporize readily. The fuel must be broken up in fine particles and sprayed into the cylinder. The atomization of fuel is accomplished by forcing the fuel through a nozzle at the top of the combustion chamber. As the fuel combines with the air in the cylinder, it becomes a combustible mixture. Since the diesel engine depends upon the heat of compressed air to ignite the fuel-air mixture, compression pressure must be maintained. Leaking valves or piston rings (causing "blow by") cannot be tolerated.

The fuel is also important. The automotive-type diesel is designed to run on a specific type or grade of fuel. Trouble can be expected if an attempt is made to use other than the proper type.

7.51 Operation

In the two-cycle engine, intake and exhaust takes place during part of the compression and power strokes; whereas, the four-cycle engine requires four strokes to complete the operating cycle. During one-half of the cycle, the four-stroke acts as an air pump. The two-stroke must have a blower (air pump) to provide the necessary air to expel the exhaust gases and recharge the cylinder with fresh air.

In the two-cycle, a series of ports surround the cylinder at a point higher than the lowest position of the piston. These are the intake ports that allow air into the cylinder. The four-cycle engine uses intake valves. The incoming air forces the expended gases out the exhaust valve, leaving the cylinder full of clean air.

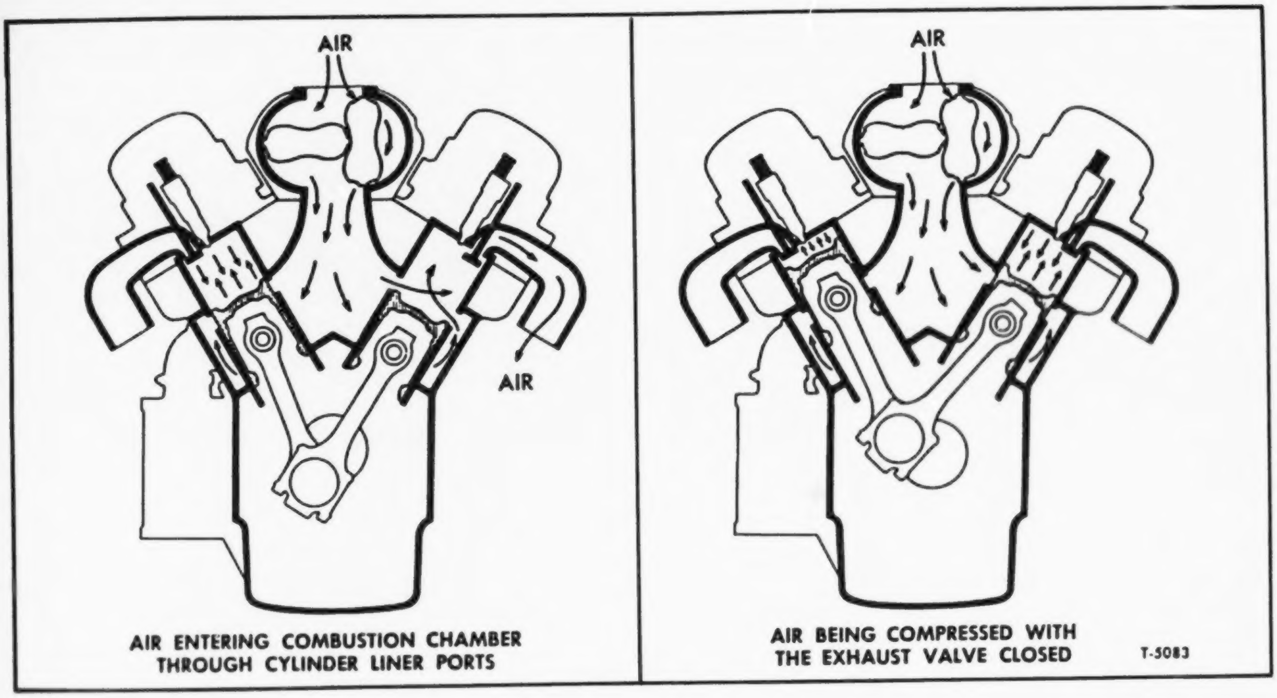
As the piston starts its upward stroke, the exhaust valve closes, the intake ports are sealed off by the piston, and the air in the cylinder is compressed. Shortly before the piston reaches the top of the stroke, the required amount of fuel is sprayed into the combustion chamber by the fuel injector. The intense heat of compression ignites the fuel-air mixture with the resulting combustion driving the piston down on its power stroke.

As the piston nears the bottom of the stroke, the exhaust valve opens and the spent gases are released; assisted by the incoming fresh air. The cycle is complete.

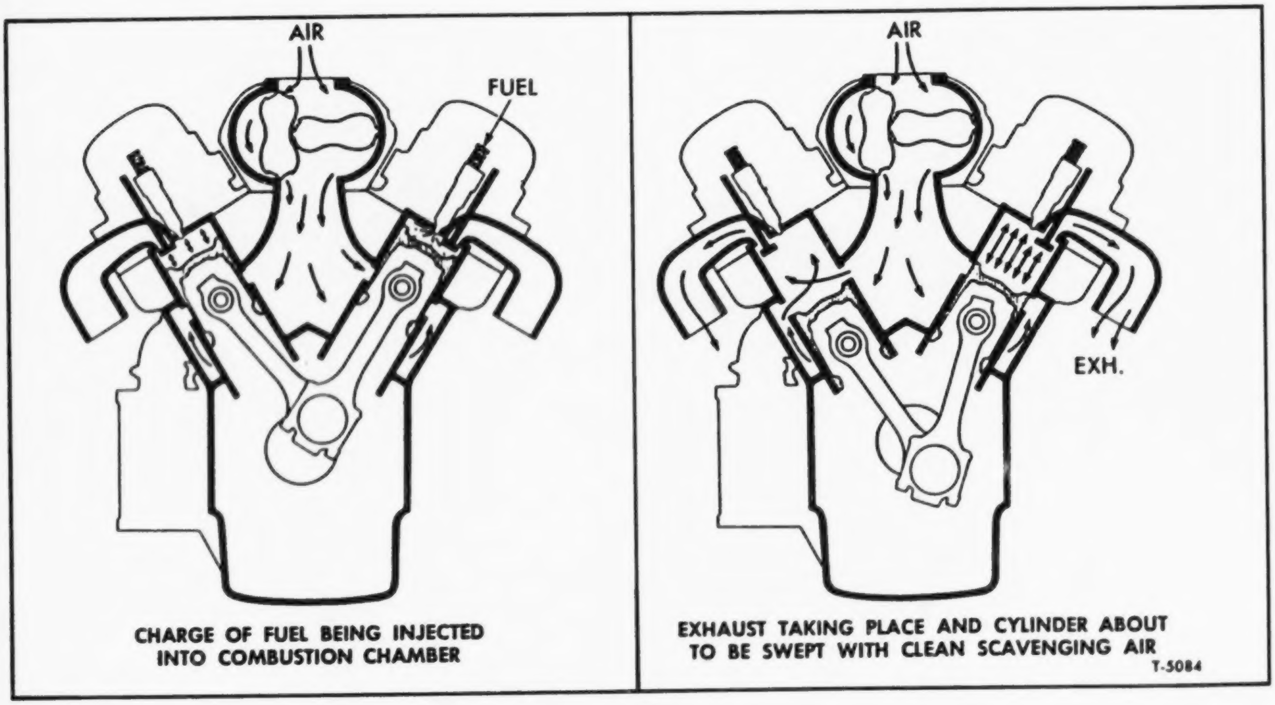
7.52 Fuel System (Fig. 7.36)

The basic parts of the fuel system are:

1. Primary fuel filter,
2. Secondary fuel filter,
3. Fuel injection pump, and
4. Fuel injector.


AIR
AIR
AIR
AIR ENTERING COMBUSTION CHAMBER THROUGH CYLINDER LINER PORTS
AIR BEING COMPRESSED WITH THE EXHAUST VALVE CLOSED
T-5083

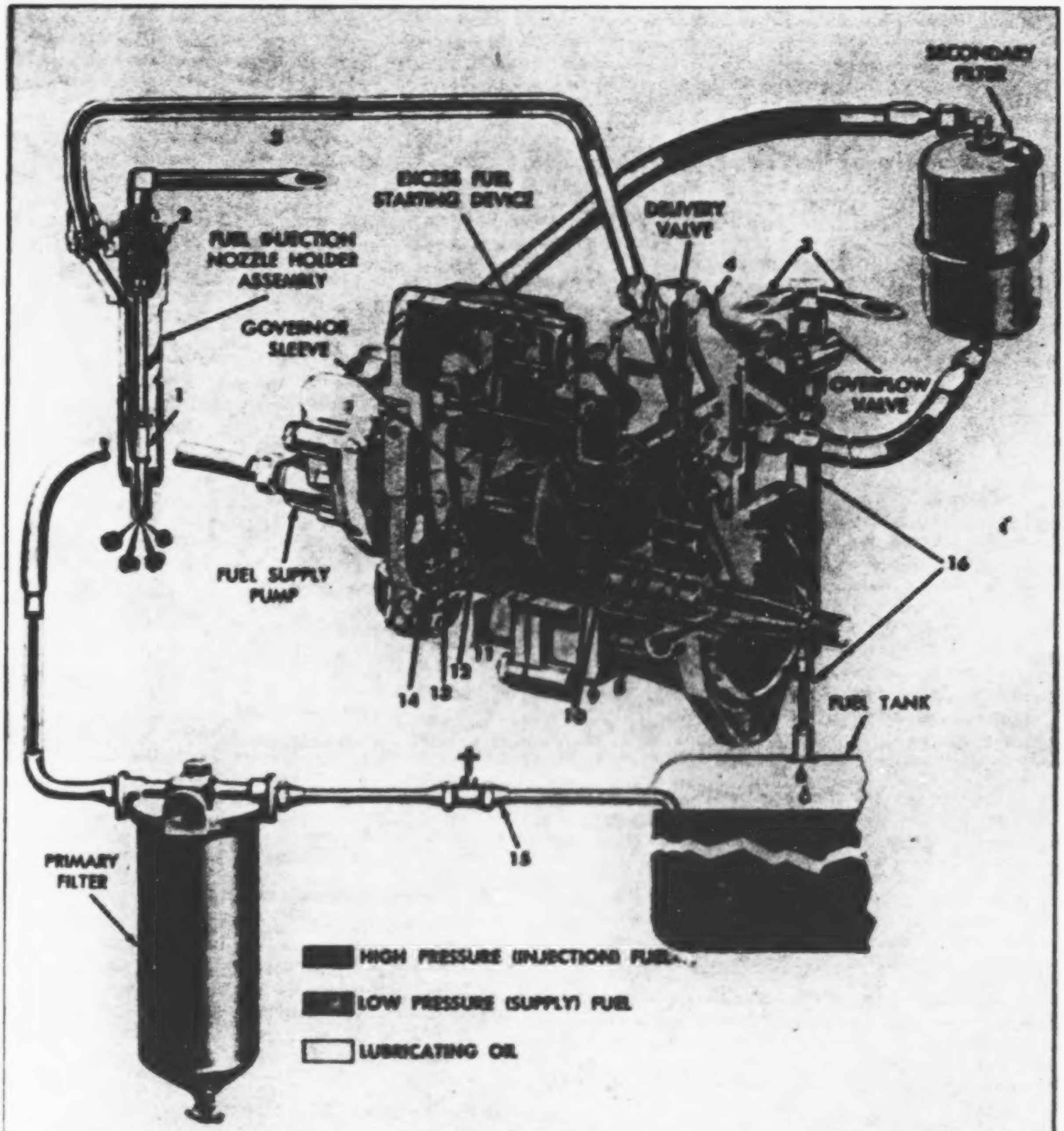
Scavenging and Compression


AIR
FUEL
AIR
EXH.
CHARGE OF FUEL BEING INJECTED INTO COMBUSTION CHAMBER
EXHAUST TAKING PLACE AND CYLINDER ABOUT TO BE SWEPT WITH CLEAN SCAVENGING AIR
T-5084

Power and Exhaust

Fig. 7.35 How diesel engines work

(Source GMC Truck Overhaul Manual Series 53, permission of General Motors Corp.)


SECONDARY FILTER
3
EXCESS FUEL STARTING DEVICE
DELIVERY VALVE
2
FUEL INJECTION NOZZLE HOLDER ASSEMBLY
4
5
GOVERNOR SLEEVE
1
OVERFLOW VALVE
FUEL SUPPLY PUMP
16
14
13
12
11
10
9
8
FUEL TANK
15
PRIMARY FILTER
HIGH PRESSURE (INJECTION) FUEL
LOW PRESSURE (SUPPLY) FUEL
LUBRICATING OIL

1	Nozzle Valve and Body
2	Nozzle Valve Spring
3	Leak-off Lines
4	Hydraulic Head Assembly
5	Fuel Metering Sleeve
6	Pump Plunger
7	Face Gear
8	Tappet and Roller
9	Cam
10	Governor Gears
11	Governor Weights
12	Governor Stop Plate
13	Fulcrum Lever
14	Stop Lever
15	Shut-off (when used)
16	Fuel Return Line

Fig. 7.36 Diesel engine fuel system

(Source Maintenance Manual, permission of General Motors Corp.)

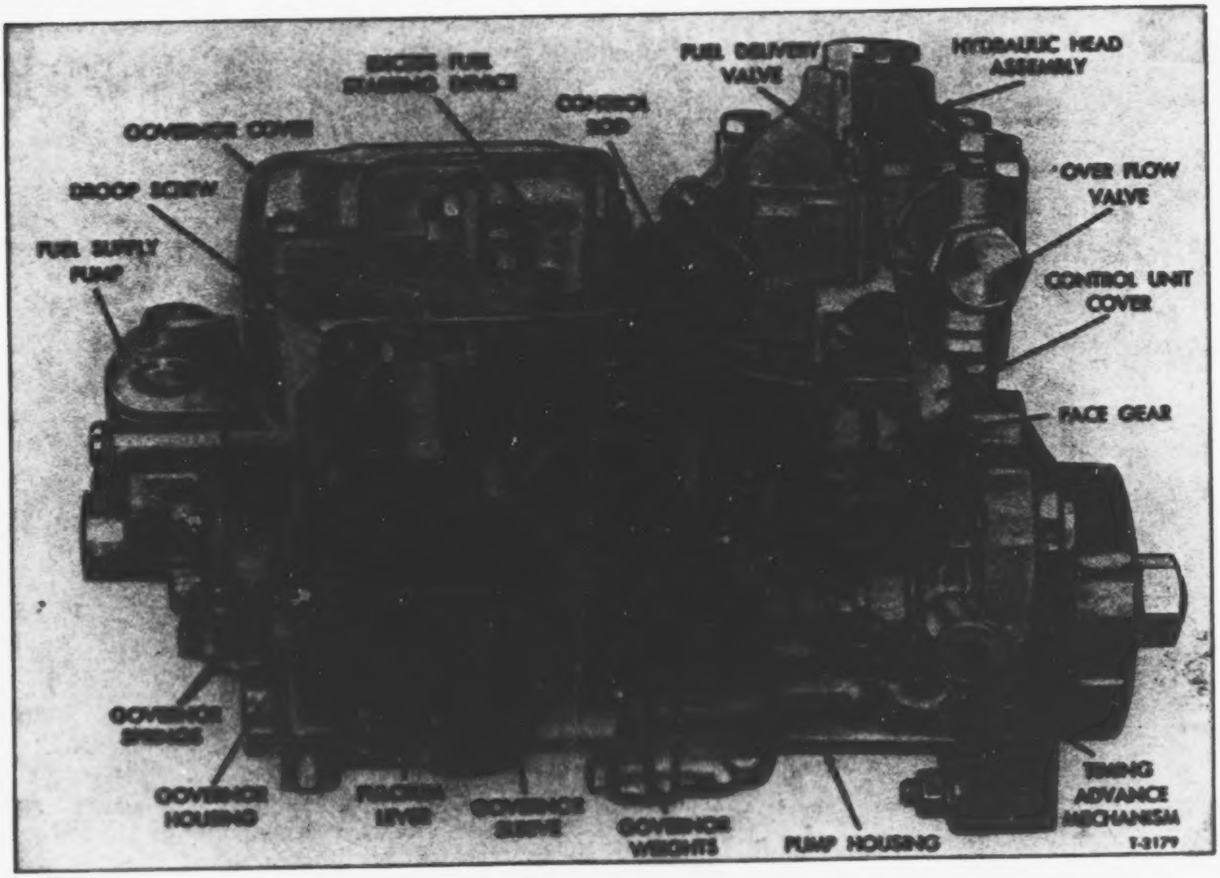

EXCESS FUEL
STARTING DEVICE
FUEL DELIVERY
VALVE
HYDRAULIC HEAD
ASSEMBLY
CONTROL
ROD
GOVERNOR COVER
DROOP SCREW
FUEL SUPPLY
PUMP
OVER FLOW
VALVE
CONTROL UNIT
COVER
FACE GEAR
GOVERNOR
SPRINGS
GOVERNOR
HOUSING
FULCRUM
LEVER
GOVERNOR
SLEEVE
GOVERNOR
WEIGHTS
PUMP HOUSING
TIMING
ADVANCE
MECHANISM
T-3179

Fig. 7.37 Cut-away view of fuel injection pump for 6-cylinder engine

(Source Maintenance Manual, permission of General Motors Corp.)

The primary filter removes all course particles from the fuel and the secondary filter removes any minute particles that remain. This ensures a clean fuel that will not clog the injector pump or fuel injectors. The heart of the fuel system is the injection pump (Fig. 7.37). This pump is a gear-type positive-displacement pump that can deliver fuel to the injector at a very high pressure. Incorporated in the pump is a timing advance mechanism to advance or retard the instant when fuel is injected into the cylinder. At high engine speed, injection would take place sooner in the cycle. The reverse happens for lower speeds.

A governor which uses centrifugal weights and is driven by the pump shaft, activates a fuel control unit. When engine speed increases, the weights are thrown toward their outer limit. Geared to the assembly, the fuel control valve is opened wider allowing more fuel to flow to the injector.

We now have higher engine speed, advanced "timing" of injection, and the necessary fuel to sustain the faster operation. When the engine is slowed, the reverse takes place.

Fuel under pressure is fed from the injection pump to the appropriate fuel nozzles. When the pressure reaches approximately 3,000 psi (90 kg/sq cm), the valve in the injector opens allowing fuel to be injected into the combustion chambers. As line pressure drops, the return spring closes the nozzle valve. Fuel left in the line is fed back to the pump through "leak off" lines.

7.53 Water-cooled Diesel Engines

Usually the larger diesel engines are of the water-cooled type, similar to gasoline engines. In order to deliver a sustained amount of high horsepower, an effective cooling system is necessary to dissipate the extreme heat of combustion. Because of this fact, a water-cooled engine of comparative horsepower to the air-cooled will cost more to manufacture, and subsequently to maintain.

7.54 Air-cooled Diesel Engines

When a lighter weight, lower horsepower, and more compact engine is desired, the air-cooled engine will serve your needs. You get the benefits of a diesel engine in a smaller package (see Air-cooled Engines, Section 7.41).

There are some definite advantages to the diesel engine over the gasoline engine. The initial cost is greater for the diesel; however, the diesel:

1. Requires less maintenance because there are:
   a. No plugs,
   b. No contact points to pit,
   c. No ignition coils or high tension wires, and
   d. Fewer tune-ups.

2. Is cheaper to operate because:
   a. Diesel fuel may be cheaper, and
   b. Better fuel efficiency.

Perhaps the biggest drawbacks against diesel engines are:

1. Initial investment costs, and
2. Repair costs.

The pros and cons must be weighed to provide you with an engine that will fill your particular needs. Whichever engine you select, remember that a well-cared-for engine will be there to serve you when it is needed and will provide trouble-free operation that is essential to most users.

7.55 How to Start Diesel Engines

Diesel engines vary in size and use and have varied starting procedures. Follow manufacturer's suggested procedures for your particular engine. As with the gasoline engine, check fuel, oil, and coolant.

To start a diesel engine, the procedures are as follows:

1. Push in "stop" control,
2. Set throttle to ⅓ full,
3. Turn on switch and engage starter, and
4. Engine should start.

Some engines have glow plugs that are energized when the switch is placed in the start position. They preheat the air-fuel mixture in the cylinder to aid in starting. After the engine is started, maintain the lower RPM's on the engine tachometer and allow the engine to warm up. The warm-up period is vital to the diesel engine for efficient engine performance. When operating the engine, maintain adequate engine RPM's as recommended by the manufacturer.

When a diesel engine will not start after repeated tries, a small amount of starting fluid sprayed into the air intake may be needed to start the engine. If you use starting fluid, do not get carried away with its use; a little goes a long way. Use it only as a last resort or as specified by the manufacturer. If your efforts have failed to start the engine, have a mechanic that is familiar with diesel engines determine the cause of the problem.

7.56 Maintenance and Troubleshooting

The following pages are from *DETROIT DIESEL ENGINES, SERIES 92 SERVICE MANUAL*. The material is reproduced with the permission of the Detroit Diesel Allison Division, General Motors Corporation. For detailed maintenance procedures for your diesel engines, see your diesel manufacturer's service manual.

TROUBLESHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

LOCATING A MISFIRING CYLINDER

1. Start the engine and run it at part load until it reaches normal operating temperature.
2. Stop the engine and remove the valve rocker covers.
3. Check the valve clearance.
4. Start the engine. Then hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.
5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.
6. If the cylinder is misfiring, check the following:
   a. Check the injector timing
   b. Check the compression pressure.
   c. Install a new injector.

Mininum Compression Pressure at 600 rpm				Altitude above Sea Level		† Air Density
Turbocharged Engines		Non-Turbocharged Engines				
psi	kPa	psi	kPa	feet	meters	
450	3101	500	3445	500	152	.0715
415	2859	465	3204	2,500	762	.0663
385	2653	430	2963	5,000	1,524	.0613
355	2446	395	2722	7,500	2,286	.0567
330	2274	365	2515	10,000	3,048	.0525

† Air density at 500 feet altitude based on 85° F (29.4° C) and 29.38 in. Hg (99.49 kPa) wet barometer.

Table 1

   d. If the cylinder still misfires, remove the cam follower and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

CHECKING COMPRESSION PRESSURE

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

Cylinder	Gage Reading	
	Psi	kPa
1L	470	3239
1R	465	3204
2L	430	2963
2R	460	3170
3L	465	3204
3R	460	3170

Table 2

2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.
3. Remove the injector and install an adaptor and pressure gage (Fig. 1) from Diagnosis Kit J 9531-01.
4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.
5. Start the engine and run it at 600 rpm. Observe and record the compression pressure indicated on the gage.

DO NOT CRANK THE ENGINE WITH THE STARTING MOTOR TO OBTAIN THE COMPRESSION PRESSURE.

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 k Pa or 1.75 kg/sq cm) at 600 rpm.

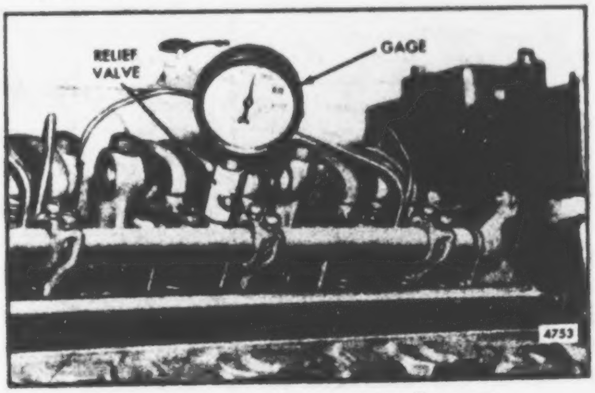


Fig. 1 Checking Compression Pressure

EXAMPLE: If the compression pressure readings were as shown in Table 2, it would be evident that No. 2L cylinder should be examined and the cause of the low compression pressure be determined and corrected.

The pressures in Table 2 are for a turbocharged engine operating at an altitude near sea level.

Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 2L cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool (Fig. 2). A broken or stuck ring will not have a "spring-like" action.

B. Compression pressure may be leaking past the cylinder head gasket, the valves seats, the injector tube or a hole in the piston.

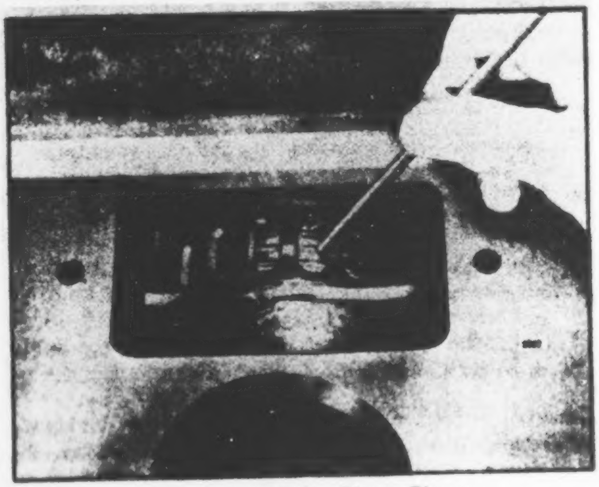


Fig. 2 Inspecting Piston Rings

ENGINE OUT OF FUEL

The problem in restarting the engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (thirty-eight liters) of fuel.
2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.
3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.
4. Start the engine. Check the filter and strainer for leaks.

NOTE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

FUEL FLOW TEST

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter when conducting a fuel flow test.

CRANKCASE PRESSURE

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

The crankcase pressure may be checked with a manometer. The manometer should be connected to the oil level dipstick opening in the cylinder block.

Check the readings obtained at various engine speeds with the *ENGINE OPERATING CONDITIONS*.

NOTE: The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

EXHAUST BACK PRESSURE

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

The exhaust back pressure, measured in inches of mercury, may be checked with a manometer in the engine diagnosis test kit J 9531-01. Connect the manometer to an exhaust manifold (except on turbocharged engines) by removing the ⅛" pipe plug which is provided for that purpose. If there is no opening provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a ⅛" pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the rear face of the turbine. The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no-load) with the specifications.

AIR BOX PRESSURE

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

To check the air box pressure, connect a manometer to an air box drain tube.

Check the readings obtained at various speeds with the *ENGINE OPERATING CONDITIONS* in Section 13.2.

AIR INLET RESTRICTION

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air intake ducting located 2" above the air inlet housing (non-turbocharged engines) or compressor inlet (turbocharged engines). When practicability prevents the insertion of a fitting at this point, on naturally aspirated engines, the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the *ENGINE OPERATING CONDITIONS*.

PROPER USE OF MANOMETER

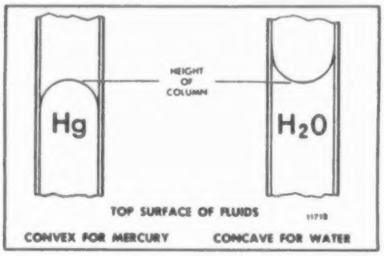


Fig. 3 Comparison of Column Height for Mercury and Water Manometers

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	.4919 psi
1" mercury	=	13.6000" water
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury

TABLE 3

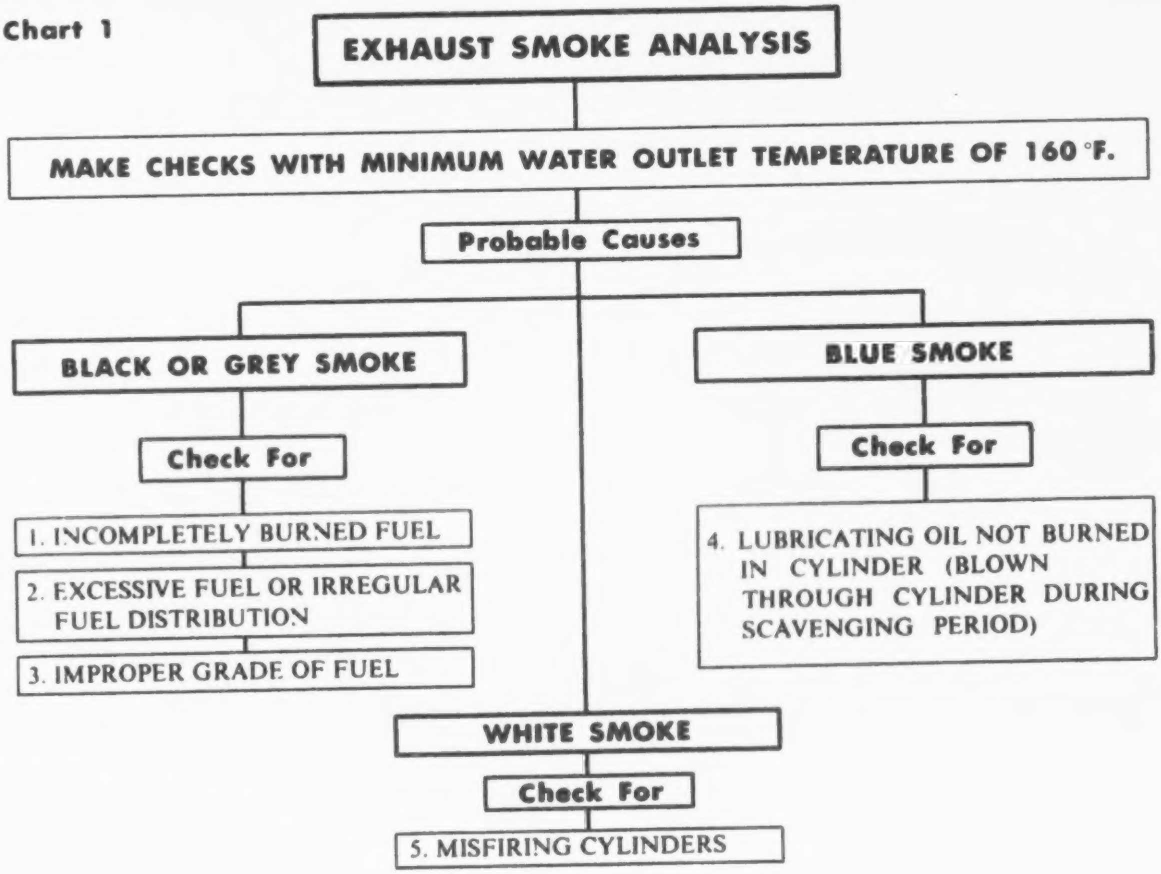
Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 3) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

Chart 1


EXHAUST SMOKE ANALYSIS
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F.
Probable Causes
BLACK OR GREY SMOKE
Check For
1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL
BLUE SMOKE
Check For
4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)
WHITE SMOKE
Check For
5. MISFIRING CYLINDERS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

   High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

   Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner, blower air inlet screen or aftercooler. These items should be cleaned. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2. Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors as outlined in *FUEL INJECTOR TIMING* and perform the appropriate governor tune-up to correct this condition.

   Replace faulty injectors if this condition still persists after timing the injects and performing the engine tune-up.

   Avoid lugging the engine below 1200 rpm as this will cause incomplete combustion.

3. Check for the use of an improper grade of fuel. Consult the *FUEL OIL SPECIFICATIONS* for the correct fuel to use.

4. Check for internal lubricating oil leaks and refer to the *HIGH LUBRICATING OIL CONSUMPTION* chart.

5. Check for faulty injectors and replace as necessary.

   Check for low compression and consult the *HARD STARTING* chart.

   The use of low octane fuel will cause this condition and can be corrected by consulting and following the *FUEL OIL SPECIFICATIONS*.

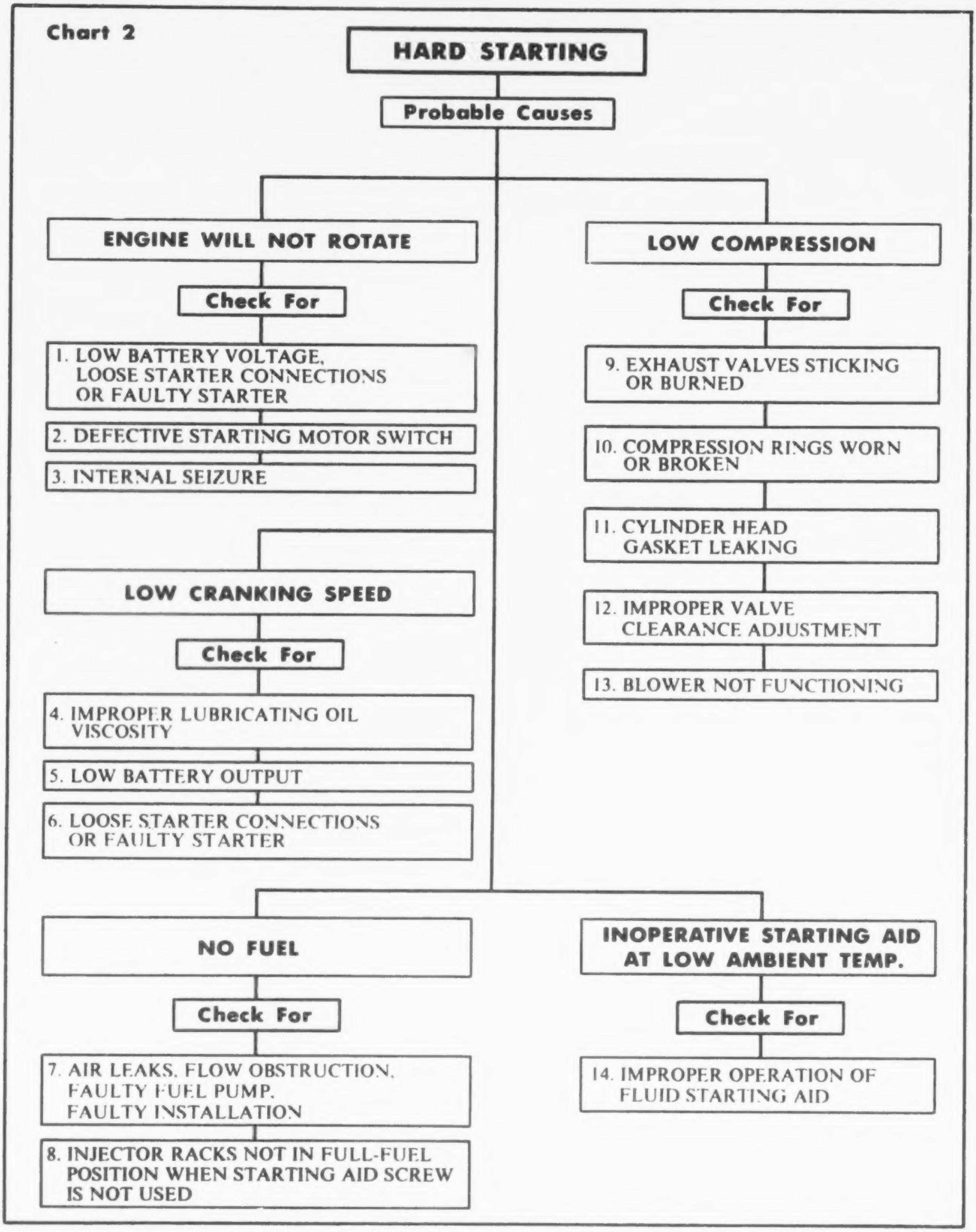


Chart 2

HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION WHEN STARTING AID SCREW IS NOT USED
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 2

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.
2. Replace the starting motor switch.
3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.
4. Use the proper viscosity lubricating oil grade as recommended in the *LUBRICATING OIL SPECIFICATIONS*.
5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

   Connect the leads properly after replacing the terminals that are damaged or corroded.

   At low ambient temperatures, use of a starting aid will facilitate keeping the battery fully charged by reducing the cranking time.
6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.
7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *NO FUEL OR INSUFFICIENT FUEL* chart.
8. Inspect for governor-to-injector linkage binding that will prevent the governor from positioning the injector racks into the full-fuel position. Remove any bind found and readjust the governor and injector controls if necessary.
9. The cylinder head must be removed and overhauled to correct this condition.
10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.
11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head compression gasket may be damaged, a seal ring damaged or dislodged or the cylinder head is cracked. Remove the cylinder head and replace the compression gaskets and seal rings.
12. Check the exhaust valve clearance and adjust to the correct clearance.
13. Remove the blower drive shaft. Inspect the blower drive shaft and drive coupling. Replace damaged parts. Bar the engine over. If the engine does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If damaged, remove and overhaul the blower.
14. Operate the starting aid according to the instructions under *COLD WEATHER STARTING AIDS*.

Chart 3

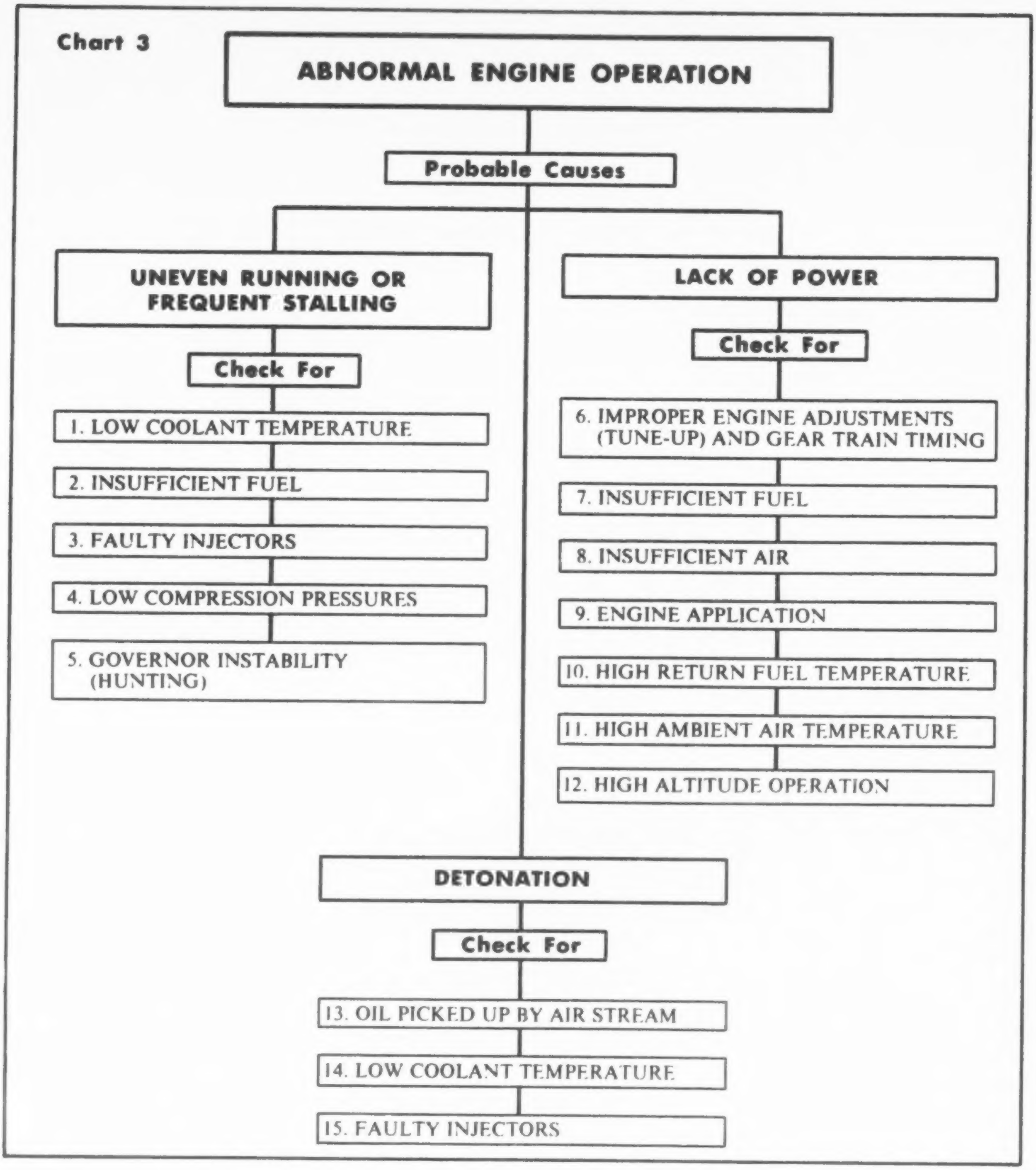

ABNORMAL ENGINE OPERATION
Probable Causes
UNEVEN RUNNING OR FREQUENT STALLING
Check For
1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)
LACK OF POWER
Check For
6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION
DETONATION
Check For
13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 3

ABNORMAL ENGINE OPERATION (Cont'd.)

SUGGESTED REMEDY

1. Watch the engine coolant temperature gage and if the temperature does not reach 160-185°F (71-85°C), while the engine is operating, consult the *ABNORMAL ENGINE COOLANT TEMPERATURE* chart.
2. Check engine fuel spill back and if the return is less than specified, consult the *NO FUEL OR INSUFFICIENT FUEL* chart.
3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.
4. Check the compression pressures within the cylinders and consult the *HARD STARTING* chart if compression pressures are low.
5. Erratic engine operation may be caused by governor-to-injector operating linkage binding or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.
6. Perform an engine tune-up if performance is not satisfactory.

   Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.
7. Perform a *FUEL FLOW TEST* and, if less than the specified fuel is returning to the fuel tank, consult the *NO FUEL OR INSUFFICIENT FUEL* chart.
8. Check for damages or dirty air cleaners and clean, repair or replace damaged parts.

   Remove the air box covers and inspect the cylinder liner ports. If the ports are over 50% plugged, clean them.

   Check for blower air intake obstruction, high exhaust back pressure or plugged aftercooler (if used). Clean, repair or replace faulty parts.

   Check the compression pressures (consult the *HARD STARTING* chart).
9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.
10. Refer to Item 13 on Chart 4.
11. Check the ambient air temperature. A power decrease of .15 to .5 horsepower per cylinder, depending upon injector size, for each 10°F (−12.2°C) temperature rise above 90°F (32°C) will occur. Relocate the engine air intake to provide a cooler source of air.
12. Engines lose horsepower with increases in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.
13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

    Clean the air box drain tubes and check valve (if used) to prevent accumulation that may be picked up by the air stream and enter the engine cylinders. Inspect the check valve as follows:

    1. Disconnect the drain tube between the check valve and the air box drain tube nut at the air box cover.
    2. Run the engine and note the air flow through the valve at idle engine speed.
    3. If the check valve is operating properly, there will be no air flow at engine speeds above idle.

    Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

    Check for a defective blower-to-cylinder block gasket. Replace the gasket if necessary. If the blower has been removed, install a new gasket.
14. Refer to Item 1 of this chart.
15. Check injector timing and the position of each injector. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Chart 4

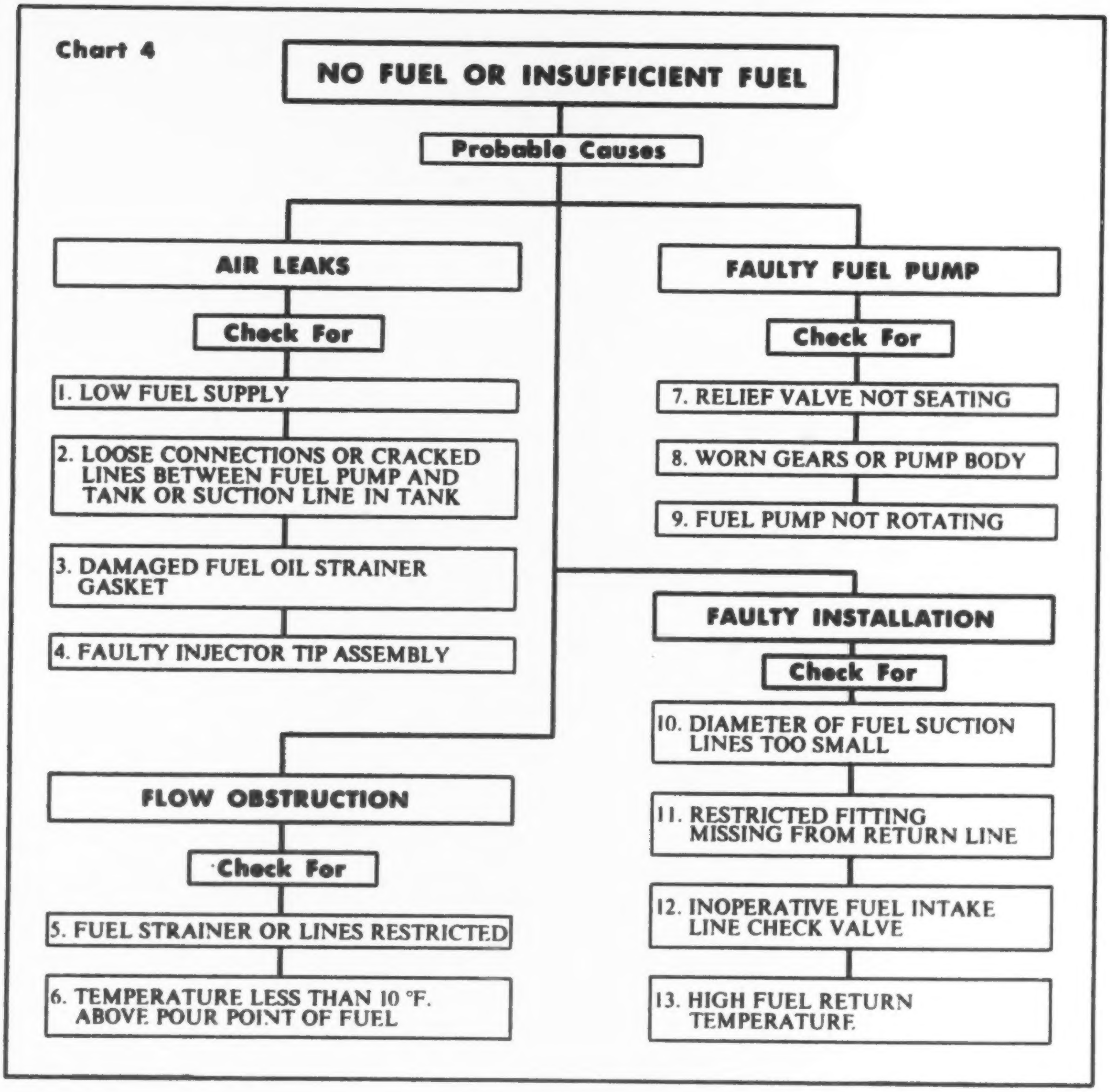

NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10 °F. ABOVE POUR POINT OF FUEL

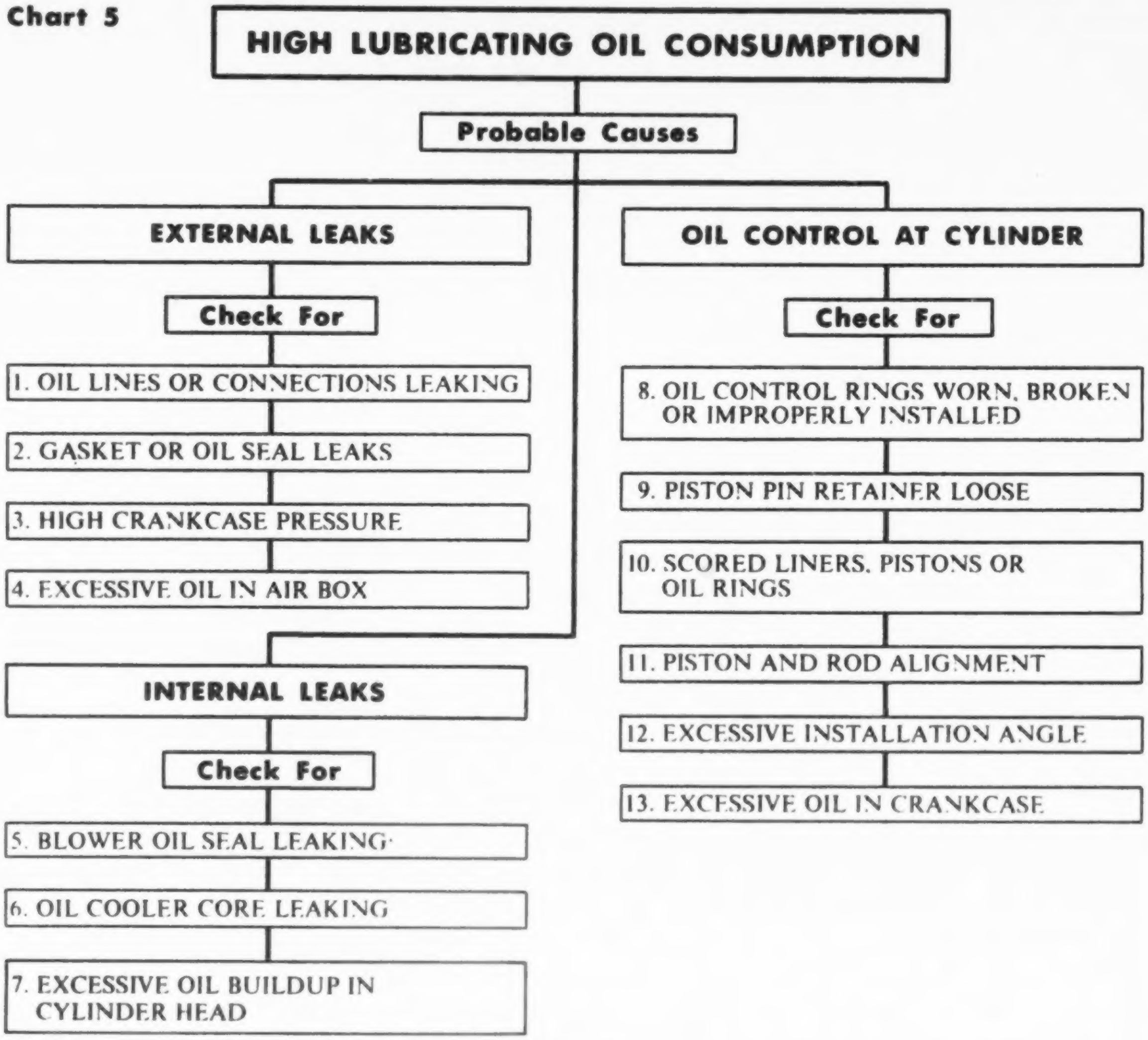
Chart 4

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.
2. Perform a *FUEL FLOW TEST* and, if air is present, tighten loose connections and replace cracked lines.
3. Perform a *FUEL FLOW TEST* and, if air is present, replace the fuel strainer gasket when changing the strainer element.
4. Perform a *FUEL FLOW TEST* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
5. Perform a *FUEL FLOW TEST* and replace the fuel strainer and filter elements and the fuel line, if necessary,
6. Consult the *FUEL OIL SPECIFICATIONS* and use the fuel oil recommended.
7. Perform a *FUEL FLOW TEST* and, if inadequate, clean and inspect the valve and seat in the fuel pump body.
8. Replace the gear and shaft assembly or the fuel pump body.
9. Check the condition of the fuel pump drive and blower drive and replace the defective parts.
10. Replace with larger tank-to-engine fuel lines.
11. Install a restricted fitting in the return line.
12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.
13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

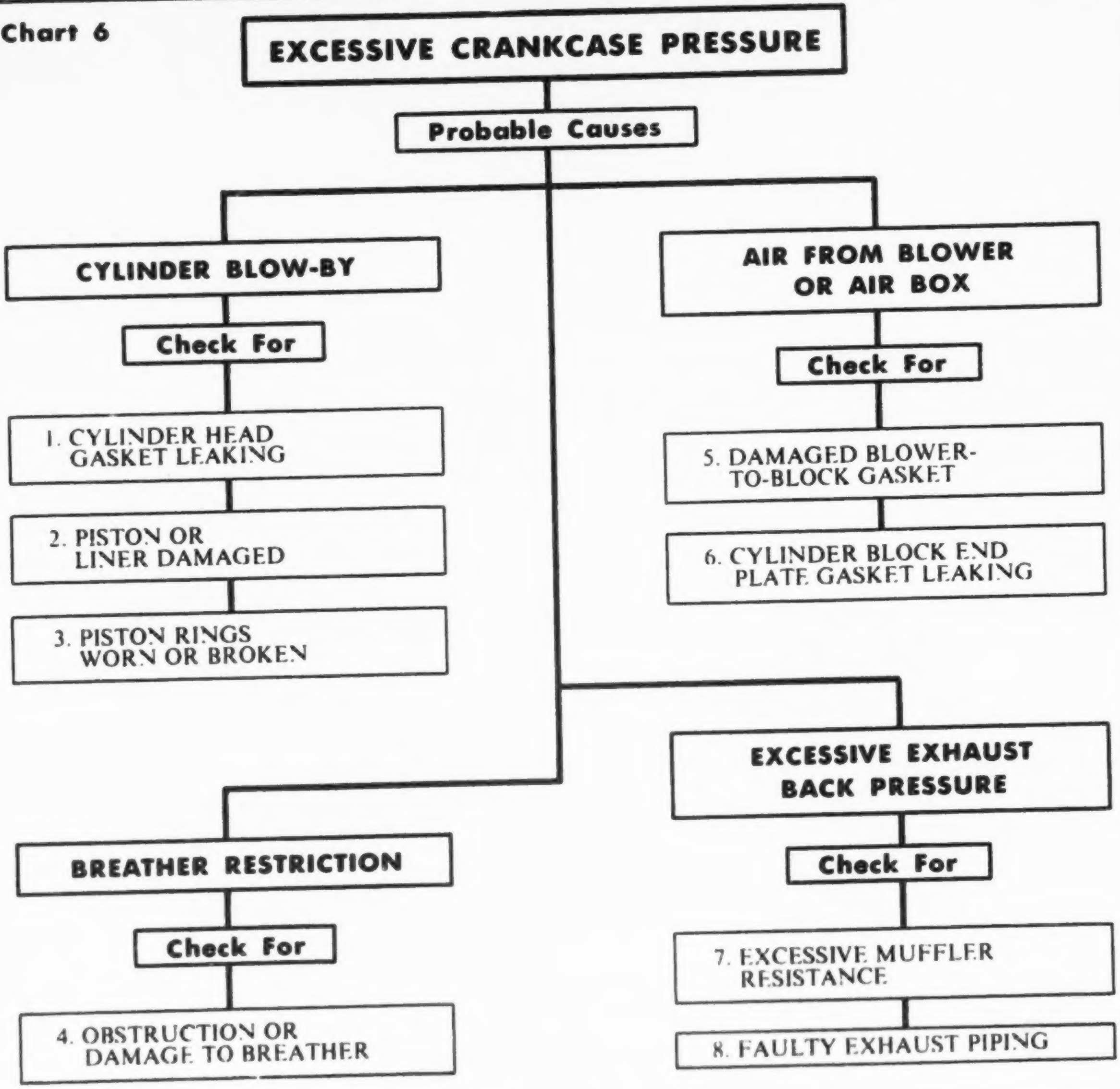
Chart 5


HIGH LUBRICATING OIL CONSUMPTION
Probable Causes
EXTERNAL LEAKS
Check For
1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. HIGH CRANKCASE PRESSURE
4. EXCESSIVE OIL IN AIR BOX
INTERNAL LEAKS
Check For
5. BLOWER OIL SEAL LEAKING
6. OIL COOLER CORE LEAKING
7. EXCESSIVE OIL BUILDUP IN CYLINDER HEAD
OIL CONTROL AT CYLINDER
Check For
8. OIL CONTROL RINGS WORN, BROKEN OR IMPROPERLY INSTALLED
9. PISTON PIN RETAINER LOOSE
10. SCORED LINERS, PISTONS OR OIL RINGS
11. PISTON AND ROD ALIGNMENT
12. EXCESSIVE INSTALLATION ANGLE
13. EXCESSIVE OIL IN CRANKCASE

SUGGESTED REMEDY

1. Tighten or replace the defective parts.
2. Replace defective gaskets or oil seals.
3. Refer to the *EXCESSIVE CRANKCASE PRESSURE* chart.
4. Refer to the *ABNORMAL ENGINE OPERATION* chart.
5. Remove the air inlet housing and inspect the blower end plates while the engine is operating. If oil is seen on the end plate radiating away from the oil seal, overhaul the blower.
6. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.
7. Check for plugged or improper breather.
8. Replace the oil control rings on the piston.
9. Replace the piston pin retainer and defective parts.
10. Remove and replace the defective parts.
11. Check the crankshaft thrust washers for wear. Replace all worn and defective parts.
12. Decrease the installation angle.
13. Fill the crankcase to the proper level only.

Chart 6


EXCESSIVE CRANKCASE PRESSURE
Probable Causes
CYLINDER BLOW-BY
Check For
1. CYLINDER HEAD GASKET LEAKING
2. PISTON OR LINER DAMAGED
3. PISTON RINGS WORN OR BROKEN
AIR FROM BLOWER OR AIR BOX
Check For
5. DAMAGED BLOWER-TO-BLOCK GASKET
6. CYLINDER BLOCK END PLATE GASKET LEAKING
EXCESSIVE EXHAUST BACK PRESSURE
Check For
7. EXCESSIVE MUFFLER RESISTANCE
8. FAULTY EXHAUST PIPING
BREATHER RESTRICTION
Check For
4. OBSTRUCTION OR DAMAGE TO BREATHER

SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
2. Inspect the piston and liner and replace damaged parts.
3. Install new piston rings.
4. Clean and repair or replace the breather assembly.
5. Replace the blower-to-block gasket.
6. Replace the end plate gasket.
7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 7

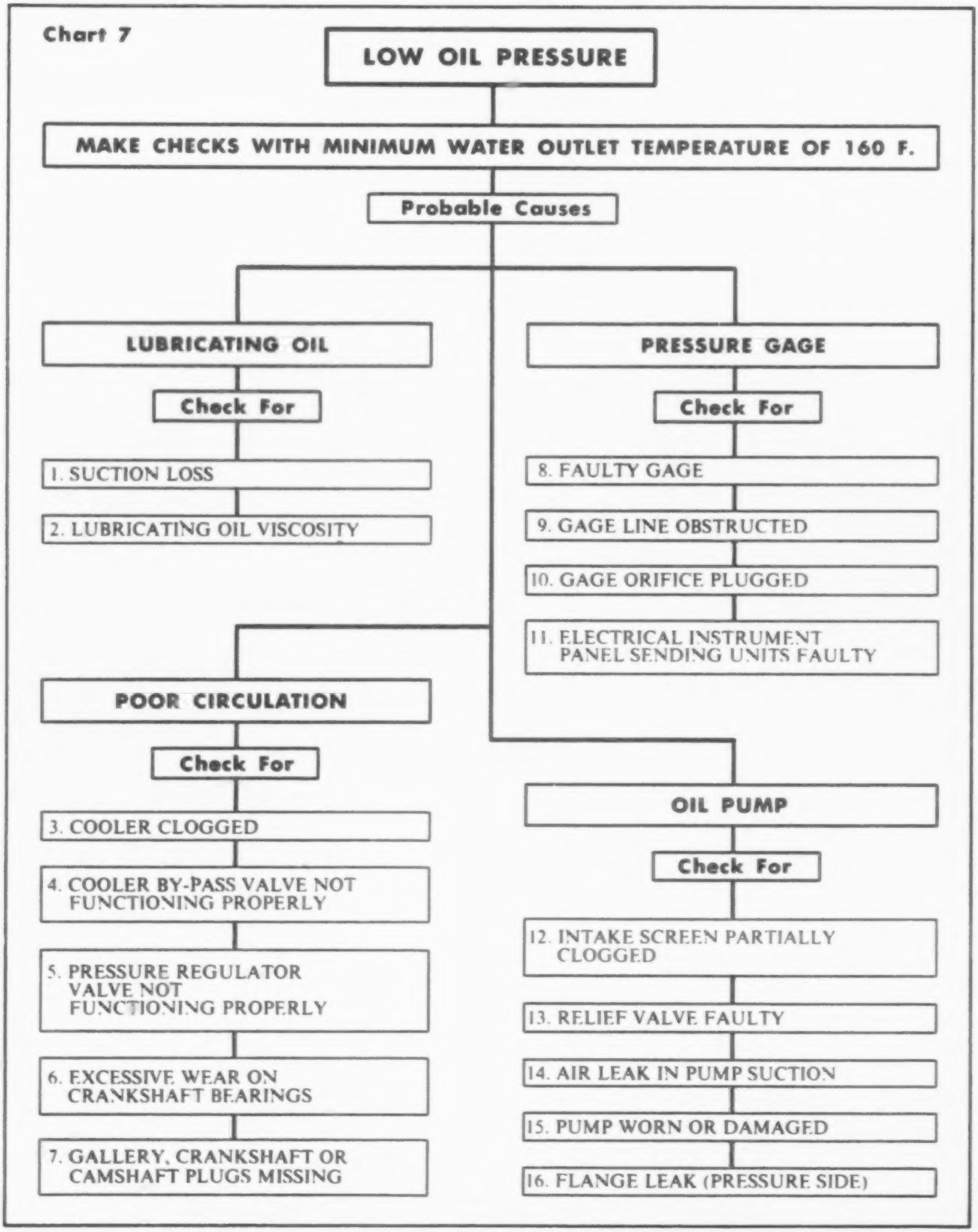

LOW OIL PRESSURE
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 F.
Probable Causes
LUBRICATING OIL
Check For
1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY
PRESSURE GAGE
Check For
8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY
POOR CIRCULATION
Check For
3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING
OIL PUMP
Check For
12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

Chart 7

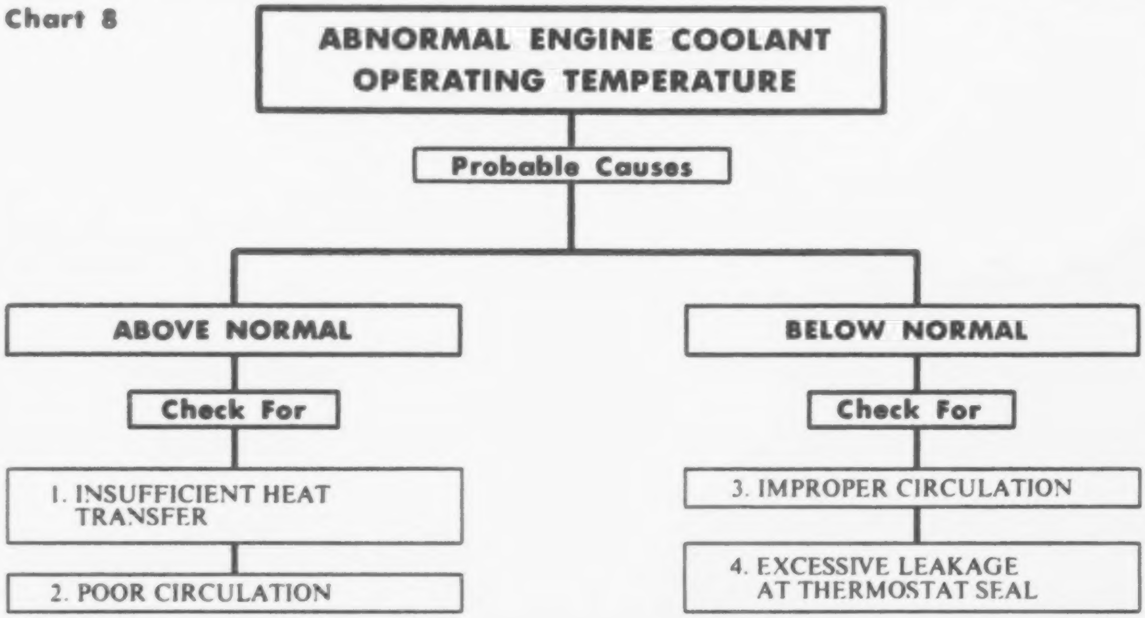
LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.
2. Wrong viscosity of lubricating oil being used; consult the *LUBRICATING OIL SPECIFICATIONS*.

    Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause fuel oil dilution.
3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.
4. Remove the oil cooler by-pass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.
5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.
6. Change the bearings. Consult the *LUBRICATING OIL SPECIFICATIONS* for the proper grade of oil to use and change the oil filters.
7. Replace missing plug(s).
8. Check the oil pressure with a reliable gage and replace the gage if found faulty.
9. Remove and clean the gage line; replace it if necessary.
10. Remove and clean the gage orifice.
11. Repair or replace defective electrical equipment.
12. Remove and clean the oil pan and oil intake screen; consult the *LUBRICATING OIL SPECIFICATIONS* for the proper grade of oil to use and change the oil filters.
13. Remove and inspect the valve, valve bore and spring; replace faulty parts.
14. Disassemble the piping and install new gaskets.
15. Remove the pump, clean and replace defective parts.
16. Remove the flange and replace the gasket.

Chart 8


ABNORMAL ENGINE COOLANT OPERATING TEMPERATURE
Probable Causes
ABOVE NORMAL
Check For
1. INSUFFICIENT HEAT TRANSFER
2. POOR CIRCULATION
BELOW NORMAL
Check For
3. IMPROPER CIRCULATION
4. EXCESSIVE LEAKAGE AT THERMOSTAT SEAL

SUGGESTED REMEDY

1. The cooling system should be cleaned with a good cooling system cleaner and thoroughly flushed to remove scale deposits.

The exterior of the radiator core should be cleaned to open plugged passages permitting normal air flow.

Loose fan belts should be adjusted to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace all faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the termostat. Install a new thermostat if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature, when this occurs, replace the thermostat seal(s).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 546.

7.5A Why is gasoline not used as a fuel in diesel engines?

7.5B List the four basic parts of a diesel fuel system.

7.5C What is the purpose of the fuel injection pump?

7.6 HEATING, VENTILATING, AND AIR CONDITIONING

This section covers the most common forms of heating (specifically digesters), ventilating, and air conditioning found in wastewater treatment facilities.

7.60 Operation and Maintenance of Digester Gas or Natural Gas-Fired Boilers

A large number of parts are similar for almost all gas-fired hot-water boilers. They will be discussed in this section.

7.600 Gas System

1. *GAS PRESSURE REGULATOR.* The gas pressure regulator is a device on the incoming gas line that regulates the pressure of the gas coming to the boiler. In a natural gas boiler, the manifold pressure should be 3.5 inches (8.9 cm) of water pressure. Methane-fired boilers would have a pressure of 2.5 to 3 inches (6.3 to 7.6 cm) of water pressure.
2. *AUTOMATIC GAS VALVE.* The gas valve opens and closes allowing the gas to flow to the burner. The valve is controlled by the operating thermostat. If the pilot valve is not operating, the circuit for gas valve closure is incomplete; therefore, the valve cannot be opened without a pilot to ignite the gas.
3. *PILOT SWITCH/VALVE.* The pilot can be of the electronic type that has no pilot flame unless the boiler falls below operating temperature. After the pilot flame has ignited, the automatic gas valve opens. When a pilot flame is called for, an ignition transformer causes an arc across its electrodes and ignites the pilot. Once a pilot is sensed by a photoelectric eye, the transformer circuit opens. The other type of pilot valve requires a "standing" pilot that heats a thermocouple and allows the pilot to remain lighted. If the pilot is extinguished, the thermocouple cools and the pilot valve closes. The automatic gas valve will not operate if the pilot is out since the electrical contacts incorporated in it are open.
4. *CONTROL TRANSFORMER.* The most common voltage used in boiler control is 24 volts, or 120 volts A.C. This supplies the voltage necessary to operate the solenoid valves.
5. *BURNERS.* The burners distribute the gas and consequently, the flame across the combustion or fire box surface. Each burner has a draft shuttle to regulate air to the burner. As the gas enters the burner, it goes through a metering orifice. When purchasing a boiler that will be fired by methane gas, make sure that you obtain the correct orifices. Natural gas orifices are too small to allow an adequate volume of methane gas to the burners.
6. *DRAFT BLOWERS.* These are installed to ensure that an adequate amount of air is available for good gas combustion. They also allow for good air circulation through the boiler core.

7.601 Water System

1. *LOW WATER CUTOFF VALVE.* This valve ensures that sufficient water is available in the boiler at all times for safe operation. If the water falls below the safe point, a set of contacts in the valve open and de-energize the circuit to the automatic gas valve. You cannot restore gas to the burner until the water level is re-established.
2. *MAKEUP WATER VALVE.* Some boilers use a float-actuated valve that monitors the water level in the boiler and adds water as needed. These boilers may have a set of contacts that open the electrical circuit, causing the burner to die when water is added.
3. *EXPANSION TANK.* This allows for the expansion of water in the boiler system. Most tanks have a sight glass so the operator can make a visual observation of the amount of water available.
4. *HIGH PRESSURE RELIEF VALVE.* If the water pressure within the vessel exceeds the maximum allowable pressure in the boiler, the valve will open and vent excess pressure.
5. *HOT WATER CIRCULATION PUMP.* Some systems use a pump to circulate the hot water from the boiler through the heat exchanger and back. If the pump should fail and the heat generated in the boiler cannot be dissipated, a high temperature cut-off shuts down the boiler.

7.602 Control Switches

1. *OPERATING SWITCH.* This switch is adjustable and an optimum operating temperature can be set. The boiler operating cycle is set by this switch.
2. *OVER TEMPERATURE CUT-OUT.* If the vessel temperature exceeds the normal operating level, the over temperature cut-out shuts down the boiler before damage results. This switch usually will have a manual reset. The boiler system will have to be examined to determine the cause of shutdown such as a low water level or a faulty operating switch.
3. *FLUE DRAFT SWITCH.* The draft switch must be closed before the burner will fire. In this way you are assured that adequate air is available before ignition takes place.

7.603 Boiler Maintenance

1. Drain boiler system sufficiently to remove sludge from bottom of boiler — yearly.
2. Test boiler switches and safety devices to insure proper operation — yearly.
3. Clean boiler if insufficient draft is suspected. The impurities of digester gas will build up in the boiler core causing the flame to flare out at the burner. Do cleaning as needed or yearly.
4. Inspect chimney for blockages and clean out soot yearly. A dirty chimney can cause restricted air flow and/or a combustible environment.
5. Blow down the level-control valve to eliminate scale and sludge buildup in the float cavity — at least twice yearly.
6. Test boiler feed water for hardness. In some cases "softened" water will have to be used. Hard water causes scale to build up inside the boiler. Scale will reduce heat transfer and thus the efficiency of the boiler.
7. Check boiler water level daily.
8. When boiler is cleaned, ensure that none of the orifices on the burner face are blocked.

Regular maintenance should be performed as outlined in the manufacturer's operation and maintenance manual.

NOTE: Never add cold water to a boiler that has been shut down because of an over temperature. This could cause a cast iron vessel to fracture. However, if the boiler water level is low, water can be added *SLOWLY* to the system.

See Table 7.3 for a troubleshooting guide and for service hints.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 546.

7.6A List the common items that are similar for almost all gas-fired hot-water boilers.

7.6B How is the automatic gas valve controlled?

7.6C Why should boilers be drained on an annual basis?

7.6D Why does boiler feed water have to be tested for hardness?

7.61 Operation and Maintenance of Building Blowers and Exhaust Fans

7.610 Need for Blowers and Fans

Because of the confined spaces found in wastewater treatment plants, it is necessary to provide adequate ventilation. Where natural ventilation is not possible or adequate, it is necessary to use blowers and fans to ensure the proper rate of air change in the area.

7.611 Terminology

These are a few terms you should be familiar with:

CFM (cubic feet per minute) — A measure of the volume flow rate, or air-moving capacity of a fan or blower per minute.

FREE AIR DELIVERY – The conditions existing when there are no restrictions to air flow at the inlet or outlet of an air-moving device.

PLENUM CHAMBER – An air chamber maintained under pressure to serve one or more air distribution ducts.

SP (Static Pressure) — The measurement of the resistance to the movement of air forced through a system caused by duct work, inlets and louvers. Static pressure is measured in inches or centimeters of water, the height in inches to which the pressure will lift a column of water. For a given system, static pressure varies as the square of the flow rate. If the flow rate is doubled, the static pressure of the system increases four times.

VENTURI – A panel surrounding the blades of a propeller fan which increases fan performance.

7.612 Fan Laws

CFM, RPM, and HP (Horsepower) are all related to one another. When one changes, the others change in a known manner. These characteristics are known as Fan Laws. CFM is the most commonly changed variable in an air system.

To change the CFM of a known or existing system the following applies:

1. Calculate the ratio between new and existing CFM.

$$\text{Ratio equals } \frac{\text{CFM New}}{\text{CFM Existing}}$$

2. To determine RPM, multiply the ratio of step one, times the existing RPM.

$$\text{New RPM equals } \frac{\text{CFM New}}{\text{CFM Existing}} \text{ times RPM Existing}$$

3. The new SP determined by multiplying the ratio of step one, times itself, times existing SP (static pressure).

$$\text{SP New Equals } \frac{(\text{CFM New})^2}{(\text{CFM Existing})^2} \text{ times SP Existing}$$

4. The new HP required is as follows: Multiply ratio of step one, times itself twice, and then times the existing HP (horsepower).

$$\text{HP New equals } \frac{(\text{CFM New})^3}{(\text{CFM Existing})^3} \text{ times HP Existing}$$

EXAMPLE

KNOWN		**UNKNOWN**
Existing Conditions		New Conditions
Flow, CFM	= 4,000 CFM	1. Speed, RPM
Speed, RPM	= 1,000 RPM	2. Static Pressure, in
Static Pressure, in	= 0.5 inches	3. Motor Power, HP
Motor Power, HP	= 0.5 HP	
New Condition Flow, CFM	= 5,000 CFM	

Determine CFM Ratio

$$\begin{aligned}\text{CFM Ratio} &= \frac{\text{New CFM}}{\text{Existing CFM}}\\ &= \frac{5{,}000\text{ CFM}}{4{,}000\text{ CFM}}\\ &= 1.25\end{aligned}$$

1. Calculate the new speed, RPM.

$$\begin{aligned}\text{Speed, RPM} &= (\text{CFM Ratio})(\text{Existing RPM})\\ &= 1.25 \times 1{,}000\text{ RPM}\\ &= 1{,}250\text{ RPM}\end{aligned}$$

2. Calculate the new static pressure, inches.

$$\begin{aligned}\text{Static Pressure, in} &= (\text{CFM Ratio})^2(\text{Existing SP, in})\\ &= (1.25)^2 \times 0.5\text{ in}\\ &= 0.78\text{ in}\end{aligned}$$

3. Calculate the new motor power, HP.

$$\begin{aligned}\text{Motor Power, HP} &= (\text{CFM Ratio})^3\ (\text{Existing, HP})\\ &= (1.25)^3 \times 0.5\\ &= 0.98\text{ HP}\end{aligned}$$

New Conditions Are: 5,000 CFM (up 25%), 1,250 RPM (up 25%), 0.78 SP (up 36%), 0.98 HP (up 95%).

7.613 Types of Fans and Blowers

There are different types of fans and blowers. Each meets different needs of ventilation.

Propeller (Axial) Fan. The air flow is parallel or axial to the shaft on which the propeller is mounted. These fans have good efficiency, near free air delivery, and are used in low static pressure, and high volume application. Usually they are mounted in a venturi. Use — Simple construction and low cost.

TABLE 7.3 TROUBLESHOOTING GUIDE AND SERVICE HINTS[a]

TROUBLE	POSSIBLE CAUSE	REMEDY
1. Pilot Outage	a. Defective Thermocouple (100% S.O.)	a. Replace
	b. Heavy Draft Blowing Across Pilot	b. Redirect Air Movement or Eliminate
	c. Plugged Pilot Orifice	c. Replace Orifice
	d. No Gas	d. Check Manual Pilot Valve Check Manual Gas Train Valve Check Manual Meter Valve Consult Gas Company
	e. Defective Pilotstat or Pilot Switch	e. Replace
2. Main Gas Valve Will Not Open (Standard System)	a. No Power	a. Check Power Source With Meter. Also Check Fuses
	b. Defective Gas Valve	b. Replace
	c. Defective Thermocouple	c. Replace
	d. Low Water in Boiler or System Causing Low Water Cut-Off to Function	d. Check for Leaks Check Feeder if Supplied
	e. Defective Pilotstat (100% S.O.)	e. Replace
	f. Defective Pilot Switch	f. Replace
	g. If Provided — Hi-Pressure Gas Switch Open	g. Check Switch Setting Check Manifold Gas Pressure
	h. If Provided — Lo-Pressure Gas Switch Open	h. Check Switch Setting Check Inlet Gas Pressure
3. Main Gas Valve Will Not Open (Electronic System)	a. No Power	a. Check Source With Meter Also Check Fuses
	b. Defective Valve	b. Replace
	c. Relay on Safety	c. Check for Pilot Outage
	d. Pilot Out	d. Relight Pilot May have Defective Pilot Valve or Ignition Transformer
	e. Defective Relay	e. Replace
	f. Low Water in Boiler or System — Lo-Water Cut-Off Functioning	f. Check for Leaks Check Water Feeder if Supplied
	g. Defective Pilotstat (100% S.O.)	g. Replace
	h. Defective Pilot Switch	h. Replace
	i. Defective Thermocouple(s)	i. Replace
	j. If Provided — Hi-Pressure Gas Switch Open	j. Check Switch Setting Check Manifold Gas Pressure
	k. If Provided — Lo-Pressure Gas Switch Open	k. Check Switch Setting Check Inlet Gas Pressure
4. Burner(s) Burning With Yellow Flame	a. Air Shutter(s) Closed Too Far	a. Adjust Air Shutters as Prescribed
	b. Low Gas Pressure in Manifold (Insufficient Air Injection)	b. Adjust Pressure Regulator or Check Line Pressure
	c. Burner Ports Partially Closed (Rust, etc.)	c. Replace Burners or Clean Parts
	d. Insufficient Air for Combustion	d. Check Size of Air Openings Provided Into Room For Combustion Air. If Not In Accordance With Recommended Practice — Correct.
	e. Incorrect Burner Orifice — (Too Large)	e. Install Correct Orifice
	f. Gas Pressure Too High In Manifold (Over-Gased)	f. Readjust Pressure
5. Gas Spillage From Draft Hood Relief Opening	a. Insufficient Chimney Draft	a.
	1. Chimney Too Low	1. Increase Height or Install Induced Draft Fan
	2. Chimney Too Small	2. Install Induced Draft Fan
	3. Blockage in Chimney	3. Remove Blockage
	4. Downdraft Caused by Chimney Location With Respect to Other Buildings, Roofs, Etc.	4. Install Chimney Cap
	b. Exhaust Fan in Boiler Room or Connecting Area	b. Remove Exhaust Fan or Isolate Fan From Boiler Room
	c. Insufficient Area Provided for Combustion Air	c. Provide Proper Area in Accordance With Recommended Practice
6. Main Gas Valve Opens No Gas Flows	a. Manual Valve Closed at Gas Train	a. Open Valve
	b. Manual Valve Closed at Meter	b. Open Valve
	c. If Provided — Test Firing Valve Closed	c. Open Valve

[a] Permission of the Pearless Heater Company, Boxertown, Pennsylvania

DUCT FAN (TUBE-AXIAL). The air flow in this fan is parallel or axial to the shaft of the propeller. The propeller is housed in a cylindrical tube or duct. This design enables duct fans to operate at higher static pressures than propeller fans. Use — Paint spray booths and other ducted exhaust systems.

Centrifugal blowers have an air flow that is perpendicular to the shaft on which the wheel is mounted. The wheel is mounted in a scroll-type housing which is needed to develop rated pressures. There are four classes of centrifugal blowers and the classes are determined by the wheel blade position with respect to the direction of rotation.

FORWARD CURVE. The tips of the blades are inclined in the direction of rotation (most common type of centrifugal blower). Use — Residential heating and air conditioning systems, light-duty exhaust system.

BACKWARD INCLINED. The tips of the blades are inclined away from the direction of rotation. Use — Commercial, heavy-duty heating and cooling systems, non-overloading characteristics.

RADIAL BLADE. Has straight blades. Use — Since the blades are self-cleaning, it is suitable for moving heavily laden air (large particles or grease-laden) in restaurants and cafes.

IN-LINE (TUBULAR CENTRIFUGAL FAN). The air flow is developed in the same manner as a centrifugal blower, but after the air leaves the impeller it is contained in a tubular housing. By means of turning vanes, it is discharged in an axial direction. Use — Can be mounted vertically or horizontally, thus providing for a simpler installation by minimizing duct turns and transitions.

7.614 Maintenance

Maintenance of ventilation fans and blowers varies with the conditions under which they operate. All ventilating equipment should be inspected and serviced *AT LEAST* on a yearly basis.

Check fan/blower housing and blades for an accumulation of dirt. Scrape off excess with a putty knife and brush off the remaining with a stiff bristle brush. Be careful that the blades are not bent or damaged during cleaning. Inspect blades for lose rivets or cracks. Check the condition of belts (belt-driven units) for cracks, adequate tension, glazing, and condition of belt sheaves. Motor and cross-shaft bearings should be lubricated. Remove grease relief plug and add grease until all old grease has been dissipated with new grease. Most greases designed for ball bearings should be adequate. When fan/blower is operating, listen for unnatural metallic sounds that could indicate fan rubbing or bearing failure. Your particular system may require inspection and maintenance at closer intervals so check the manufacturer's recommendations.

7.62 Operation and Maintenance of Air Conditioning Units

A brief explanation of how a refrigeration system works will help you understand how air conditioning units work. Refrigeration has been defined as the process of transferring heat from one place to another. When a hot object is placed near or touches a cold object, heat flows from hot to cold. In refrigeration, take the viewpoint that a cold object removes heat from a hot object. The term "refrigerant" refers to the fluid used in the system to produce cold by removing heat. One of the early refrigerants was ammonia. When ammonia is placed in an open container, it evaporates so rapidly that it appears to be boiling. When pure ammonia boils, it cools to 28 degrees below zero F (−33°C). The area from which the boiling ammonia removes heat is cooled or refrigerated.

The refrigerant gas in enclosed systems is reclaimed (not allowed to boil off) through the process of absorption and evaporation. See Fig. 7.38 showing a refrigerator using ammonia as a refrigerant. The basic operating cycle shows that the system picks up heat in the evaporator and carries it outside the insulated refrigerator box to the condenser. Here, heat is removed by air passing over the condenser fans. The cooling effect is produced in the evaporator by boiling the refrigerant. The boiling refrigerant (−28 degree F or −33°C) absorbs heat from the interior of the box. Hydrogen is circulated over the liquid ammonia to speed up the boiling process and to carry away the heat at a faster rate.

The refrigerant is changed back to a liquid by removing heat in the condenser. At that point the refrigerant "gives up" heat. Because the heat is moving from a low temperature to a higher one, it is necessary to add energy to the system. Usually the energy is supplied in the form of heat energy. In modern refrigeration systems, the heat is produced by compressing the refrigerant vapors. Freon 12 fills the requirement as a refrigerant and is used extensively in current systems.

The air conditioner works very much like the refrigerator. Air is passed over the evaporator and the heat is removed. The cool air is then distributed through the building via "cold" air ducts. In the old axiom, "What goes in must come out," the warm air in the building is returned through "return air" ducts and passes over the condenser. The air passing over the condenser helps dissipate the heat in the refrigerant, converting it back to a liquid.

Most air conditioning units require little mechanical maintenance. The compressor is sealed and requires no external lubrication. Most fan motors have sealed bearings. Check yours to be sure. There are some things that need to be done however. The filters in the cold and return air ducts should be replaced yearly. If an undue amount of dust is present, they may require earlier cleaning or replacement. The condenser should be cleared of obstructions. Blow out with a low pressure air. Examine fan blades for fractures and excessive dirt buildup. With the power off, spin the fan to determine if bearing failure is imminent. Make sure that the condensation drip line is not plugged.

An air conditioner compressor can freeze up (completely covered with ice). This usually occurs when the air in the building becomes extremely cool or the compressor is not allowed to cycle (non-cooling). The compressor will not cycle if the thermostat is set too low or is in a manual mode. If your air conditioner unit runs but fails to cool, it is quite possible that some of the refrigerant charge may have been lost. This may be caused by a small hole in the tubing. At that point, call upon a reliable air conditioning service to correct the problem.

Because of the emphasis on energy conservation, the thermostat should be set to maintain a moderate room temperature; 74 degrees to 78 degrees F (23 to 26°C). If air conditioners in your building are usually left on during non-working hours, time-clock-actuated thermostats that turn off the unit during off hours and back on again prior to the work day may be to your advantage.

QUESTIONS

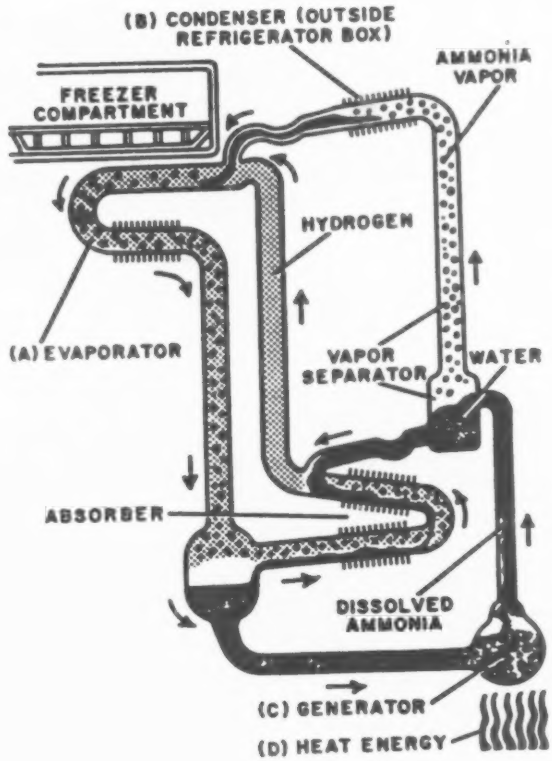
Write your answers in a notebook and then compare your answers with those on pages 546 and 547.

7.6E What is a plenum chamber?

7.6F List the four classes of centrifugal blowers.

7.6G What is refrigeration?

7.6H What might be wrong if an air conditioner runs, but fails to cool?


(B) CONDENSER (OUTSIDE REFRIGERATOR BOX)
AMMONIA VAPOR
FREEZER COMPARTMENT
HYDROGEN
(A) EVAPORATOR
VAPOR SEPARATOR
WATER
ABSORBER
DISSOLVED AMMONIA
(C) GENERATOR
(D) HEAT ENERGY

SCHEMATIC DIAGRAM OF
BASIC ABSORPTION CYCLE

Fig. 7.38 Refrigeration system

(Source Principles of Refrigeration by Marsh and Olivo, permission of Delmar Publishers Inc., Albany, New York)

7.7 COMPRESSORS (See Vol. II, *OPERATION OF WASTEWATER TREATMENT PLANTS*, pgs 24 and 25)

7.70 Need for Compressors

With pneumatic tools and instrumentation filling a vital part of our needs, it is important to look at and understand the heart of any air system — the compressor. Basically there are two types of air compressors, rotary and reciprocating. You will find that there are some variations in design but the principles of operation are similar for comparable machines.

7.71 Rotary Compressors

Rotary compressors usually fall into one of two categories, single stage or two stage. In either case, they have sliding vanes and use oil to cool the compressor as well as lubricate and assist in sealing.

The rotor chamber (cylinder) is mounted on a base which supports the compressor. The cylinder has air inlet and discharge ports and oil injection holes. The cylinder bore is offset from the rotor shaft causing the cylinder bore to be eccentric with the rotor.

The rotor is slotted to receive sliding vanes which are sealed by a large volume of lubricating oil that is fed to the bearings and bore. The vanes are held against the cylinder wall by centrifugal force when operating. (Low RPM compressors use a spring-loaded vane to insure a vane-to-bore seal.)

As the rotor turns, air is pulled into the compressor through the intake port. Since the bore is eccentric with the rotor, displacement is decreased as the rotor turns. The air entrapped between the vanes is compressed. Lubricating oil assists to form a seal between the vane and the cylinder wall. Compressed air is expelled through the discharge port and the cycle renews itself.

Since the oil plays a major role in a rotary compressor, let's follow it through the system.

Relatively cool lubricating oil, supplied by an oil pump, is induced under pressure to the rotor bearings and also injected in measured amounts into the rotor chamber. The oil passes through the bearings at each end of the rotor, then enters the close clearances at the vane ends and then passes into the rotor chamber. All of the oil introduced mixes with the air being compressed and passes on with it. This removes the heat of compression to some degree and allows a low final air discharge temperature. Discharged air passes on to the receiver-separator. There the oil is removed from the air and collects in the storage reservoir. The oil is then forced on to an oil cooler. Air pressure causes the oil to flow through the cooler, oil filter, and back to the oil pump sump.

The two-stage compressor develops a low air pressure in the first stage (30 psi or 2.1 kg/sq cm). Oil-saturated air is then passed on to the second stage where the air is compressed even further. The remaining air/oil cycle is similar to the single stage. Some compressors incorporate a thermostatically controlled bypass valve that allows some of the oil to bypass the oil cooler. This arrangement helps to maintain a high compressor oil temperature, thereby reducing the possibility of water vapor condensation in the oil system. At a temperature near 185 degrees F (85°C), all oil is circulated through the cooler.

A nonadjustable oil pump relief valve prevents overpressure in the oil system. Many units have a high temperature and high pressure cut-off switch to insure adequate compressor protection.

When a rotary compressor is driven by an engine, a speed/pressure regulator motor monitors the air pressure versus engine speed. If air pressure declines, engine speed is increased to produce the needed air. Conversely, engine speed reduces to an idle when maximum pressure is attained. (Compressors driven by electric motors are usually operated at a set speed for a specific volume of air.)

Most engine-powered compressors have an automatic blowdown unloader valve. When the compressor stops and air pressure in the compressor and system equalize, the valve opens and blows down the system to atmospheric pressure. Be aware of the control valves and switches used in your particular system. If any malfunction is indicated, discontinue the use of the compressor until repairs are made.

Since oil plays a large part in compressor operation, it is very important that the proper oil be used. In high volume and pressure units, the recommended oil is a non-detergent straight mineral oil (turbine or hydraulic type) which is solvent refined and contains rust and oxidation inhibitors and anti-foam additives. Viscosity is in the 150-200 Saybolt universal seconds range at 100 degrees F (38°C). Check your owner's manual for further specifications.

Follow owner's manual recommendations with respect to oil changes, air filter changes, condensate draining, and examination of internal parts (vanes, rotor, and cylinder). See Table 29.4 for a compressor troubleshooting guide.

When purchasing a rotary compressor, check the specifications for the following items:

1. Rated capacity in CFM,
2. Rated operating pressure,
3. Duty cycle — intermittent or continuous,
4. Horsepower requirements, and
5. Stages.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 547.

7.7A What are the two most common types of air compressors in use today?

7.7B What type of oil is used in high volume and pressure compressor units?

7.7C List the items that are important considerations when purchasing a rotary compressor.

TABLE 7.4 COMPRESSOR TROUBLESHOOTING GUIDE[a]

MALFUNCTION	PROBABLE CAUSE	PROBABLE REMEDY
Compressor fails to operate or to provide rated capacity.	1. Clogged Air Cleaner, cap and/or screen.	1. Clean
	2. Pressure Regulator improperly adjusted.	2. Adjust Regulator
	3. Engine fails to develop proper R.P.M.'s.	3. See Engine Manual.
	4. Broken, sticking, or excessively worn rotor vanes.	4. Replace with a complete new set.
	5. Broken drive coupling.	5. Replace drive coupling.
	6. Faulty Dump Valve.	6. Replace.
Oil Gage fails to indicate pressure.	1. Defective Gage.	1. Replace.
	2. Clogged line or fitting.	2. Clean.
Excessive Compressor oil consumption.	1. Clogged Separator return line.	1. Clean.
	2. External oil leaks	2. Tighten or replace fittings, etc.
	3. Saturated Oil Separator elements.	3. Replace Separator Filter element.
Air Receiver Safety Valve activates.	1. Air Intake Valve malfunctioning.	1. Repair or replace.
	2. Speed Control malfunctioning.	2. Repair or replace.
	3. Air leaks, broken or cracked tubing.	3. Repair.
Air Receiver Safety Valve blows due to malfunctioning Air Intake Valve.	1. Incorrect control pressure from Pressure Regulator.	1. Adjust or replace Pressure Regulator.
	2. Ruptured Air Intake Valve bellofram.	2. Replace bellofram.
	3. Valve binding on Air Intake Valve shaft.	3. Repair or replace.
Air Receiver Safety Valve blows due to malfunctioning Speed Control	1. Ruptured Speed Control bellofram.	1. Replace bellofram.
	2. Incorrect control pressure from Pressure Regulator.	2. Adjust or replace Pressure Regulator
Leaks General: — Oil — Air	1. Cracked or broken tubing.	1. Replace.
	2. Loose and/or broken flares or connections.	2. Tighten and/or replace.
	3. Faulty oil seal.	3. Replace.
	4. Loose retainers.	4. Tighten.

[a] permission of Le Roi Division, DRESSER INDUSTRIES, INC., Sidney, Ohio.

7.72 Reciprocating Compressors

The operation of a reciprocating compressor is similar to that of an internal combustion engine. However, a reciprocating compressor requires an external power source to provide compression and force the air into the receiver.

Compressors can have more than one cylinder, just like engines. For the sake of clarity, however, a single-cylinder single-stage unit will be described. The compressor consists of an oil-filled crankcase which houses the crankshaft, a connecting rod and piston, a cylinder that has external cooling louvers, and a head with intake and discharge valves. The receiver (air tank) is the vessel for compressed air containment.

When the crankshaft rotates to its low position, air is drawn into the cylinder through the intake valve. As the piston begins its upward thrust, a positive pressure in the cylinder closes the intake valve. The exhaust valve is opened and the air being compressed is forced into the receiver. As the piston starts its downward stroke, new air is pulled in and the cycle is repeated.

Just as an engine has rings on the piston to aid in compression, so does the compressor. The cylinder is lubricated by the oil in the crankcase and the rings, assisted by the oil, make a seal against the cylinder wall.

The intake and discharge valves on the cylinder head, while accomplishing the same result as an internal combustion engine, are quite different. In an engine, the valves are timed to the crankshaft operation and open and close accordingly. The compressor relies on the compression and decompression of air in the cylinder to actuate the valves.

Sticky intake valves will either prohibit or reduce air intake and sticky discharge valves will reduce or prevent compression. If the intake is stuck open, air will be forced back to the atmosphere. On the other hand, a stuck exhaust allows air to move into the receiver on half of the stroke and draws it back into the cylinder on the other half.

If the compressor fails to build up pressure, place your hand over the intake. It should draw your palm down. Check the discharge in the same manner to see if air is expelled. The problem could be in the unloader, however.

Many units have air unloading intake valves and hydraulic or centrifugal unloaders. In a compressor that runs continually, the intake valves are unloaded when the high pressure point is reached. A small copper line connects the valve to the unloader and then to the air receiver. The unloader may be either electrically or mechanically actuated. The unloader operates at high pressures and allows the pressure of the receiver to compress a diaphragm in the intake valve and hold it open. With the valve in an open condition, air is pulled in and expelled through the air intake. After the compressor cycles to a non-compressing mode, the sound is similar to a dog panting. When pressure in the receiver diminishes, the valve is allowed to close and compressing resumes.

The hydraulic and centrifugal unloader are used in compressors that stop and start frequently. When in a static condition, the air valve of the unloader allows receiver air pressure to hold the intake valves open. As the compressor starts, the oil pump in the crankcase starts to pump. After pressure increases sufficiently, the loader is activated allowing the intake valve to close. So with the centrifugal, the unloading valve closes as compressor speed picks up. A faulty unloader will not let the intake valves remain open and the compressor will have to overcome the air pressure of the receiver when starting. Most compressor prime movers cannot develop the starting torque needed to overcome the pressure.

When selecting a location for the air compressor, locate it as near as possible to the point where compressed air is being used. The compressor must have an ample supply of cool, dry, and well circulated air. Compressors with fly wheels that assist in air circulation over the cooling fins of the compressor should be installed no closer than twelve inches (30 cm) from a wall. This will allow for ample air circulation. Make sure pulleys and drive belts are enclosed in an OSHA-approved belt guard assembly.

Air intake to the compressor should be clean, cool, and dry to provide satisfactory operation. An air filter is installed on the compressor intake. (Service in accordance with manufacturer's recommendations.) The air filter will usually be of the dry type but if the compressor is in a location where considerable dust and other contaminants are prevalent, an oil bath filter may be used. If it is necessary to pipe to the intake air from a cool air source, the intake pipe should be one pipe size larger for each eight feet (2.4 m) beyond the intake port of the compressor. When the intake air is drawn from the outside, a hood should be installed to prevent rain from entering the intake of the compressor. Discharge piping should be of sufficient size that the pressure drop between the receiver and the point of use is less than 10 percent. Use pipe fittings that offer the least resistance to air flow (long radius elbows and gate valves). Discharge piping should be sloped away from the receiver and a drop leg installed at its lowest point. This allows condensation to drain away from the receiver so it can be drained off at the top leg valve.

Compressors are designed to operate at certain minimum and maximum speeds. When making changes, consult your owner's manual or factory representative for the operating guidelines for your machine.

Crankcase oil should be of a given SAE viscosity depending upon ambient temperature. The type of oil used may vary with operating conditions (check your owner's manual). Change oil as specified by the manufacturer. Oil-less compressors do not use oil as a sealant to piston rings. In some cases, a carbon ring is used, having a low friction resistance. Another method is teflon rings. The main purpose is to provide air that is free of oil vapor that may gum pneumatic contols. Oil in the receiver can cause a hazardous situation (possibility of combustion). Therefore, expel any water and oil from the receiver on a regular basis.

7.73 Air Systems

When we think of air systems, we usually divide them into two basic groups:

1. Control — used for pneumatic instruments; and
2. Power System — operating high-volume pneumatic tools.

There are a number of components associated with air systems whose purpose we should understand.

FILTER. A device connected into the air line to trap solid or liquid particles that can contaminate and damage equipment. The selection of the filter requires consideration of need, depending on elements to be removed from the air. Other considerations include:

1. CFM of air to be filtered;
2. Working pressure;
3. Pressure drop across the filter; and
4. Filtration size. The element is usually measured in thousandths of an inch or microns (0.001 inch equals 25 micrometers (microns)).

PRESSURE REGULATOR. An adjustable valve used to reduce air pressure from the receiver level to that required by the air-using equipment and to maintain it automatically. The regulator may be installed near the tank or at the point of connection for the equipment.

LUBRICATOR. A device used to provide constant feeding of oil mist into the air stream for the lubrication of air-powered equipment or tools.

Air taken from the atmosphere by the compressor contains many impurities including water vapor, dust, oil, and smoke. These contaminants can cause rapid wear, clogging, and erratic operation of air tools, instruments, cylinders, and valves. There are various types of air-cleaning equipment that can help insure efficient operation of air-powered equipment.

AFTER COOLERS. Used to remove water vapor from the compressed air by lowering the temperature of the air and causing the water vapor to condense into droplets for easy removal. After coolers are of the following types:

1. Water-cooled types use an external heat exchanger and an external water supply to cool the compressed air; and
2. Air-cooled types use ambient air to cool the compressed air. Air circulates over and between the cooling louvers of the heat exchanger.

REFRIGERATED AIR DRYERS. These dryers are used to reduce the compressed air temperature to as low as 35 degrees F (1.7°C) to remove greater amounts of water than the after cooler. Piping dryers close to the work allow for cooling only that portion of air needed for a specific function. Installing an after cooler before the dryer may add to its effectiveness.

A separator/drain trap allows for easy removal of condensed waters and contaminants. Some systems use an automatic-draining condensate trap. When the condensed water volume is sufficient, it activates a float-operated valve. Condensate is ejected from the system by the compressed air. Automatic traps should be inspected frequently to ensure proper operation.

Where further moisture removal is needed (as for control instruments), compressed air, after passing through the after cooler and dryer is passed through a filter of absorbent material. Compressed air used for control instruments must be of the highest possible quality. This air must be free of water, oil, water or oil vapors, and all particulate matter. A typical system includes after cooler, refrigerated dryer, and absorbent filter (no lubricants are used). Silica-gel is a common filter element. When the element reaches its saturation point, a moisture-sensitive tab changes color indicating that replacement is needed.

The pipe size used in air distribution systems should be large enough to keep the pressure drop between the tank and the point of use at a minimum. The main air line should be no smaller than the compressor outlet. All outlets should be taken from the top of the main line (tees facing up) to keep moisture out. Check all piping and fittings regularly to avoid leaks in the system. Filters, regulators, and other accessories should also be properly maintained.

All hose bibs for high-pressure air should be marked in accordance with current regulations. In shops and buildings where air may be used for other than power applications, it should be regulated to 30 psi (2.1 kg/sq cm). This pressure is safe and adequate for use to clean equipment and other shop uses.

Never direct a high-pressure air hose on yourself or a fellow employee. Minute particles in the air can be forced into the skin. Any opening to the body, including cuts, should be safeguarded against pressurized air. Air entering the blood system can cause serious medical problems and may lead to death.

Compressed air is a versatile form of power, use it wisely and safely. When air is used to blow dust and dirt from employees' clothing, the air pressure must not exceed 10 psi (0.7 kg/sq cm).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 547.

7.7D What problems can be caused by sticky valves in a reciprocating compressor?

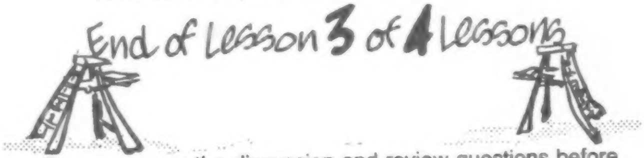
7.7E What type or kind of air should be fed to a compressor?

7.7F How is a compressor protected if the intake air contains considerable dust or other contaminants?

7.7G List the major components for power air systems.

7.7H Where should outlets from the main line of an air system be taken?

7.7I What is the main difference in components in air systems used for power tools as compared with air systems used for pneumatic control?


End of Lesson 3 of 4 Lessons

Please answer the discussion and review questions before continuing with Lesson 4.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 4 Lessons)

Chapter 7. MAINTENANCE

Write your answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

13. What is the purpose of the filters in the diesel fuel system?
14. What are the advantages of air-cooled diesel engines as compared with water cooled types?
15. What is the major difference between the burner orifices for methane gas and those for natural gas?
16. Why is adequate ventilation necessary in wastewater treatment plants?
17. What could be the causes of a compressor oil gage failing to indicate pressure and how could each cause be corrected?
18. Why should you never direct a high pressure air hose on yourself or a fellow employee?

CHAPTER 7. MAINTENANCE

(Lesson 4 of 4 Lessons)

7.8 WATER SYSTEMS

7.80 Avoid Cross Connections[9]

The water systems in a wastewater treatment plant are distinctly divided into two separate systems. Number 1 is the fresh or potable water supply for the building plumbing needs. Number 2 is the reclaimed water used for washdown, irrigation, and cooling water for pump seals and packing. You must safeguard against cross connections between the two systems. Both systems can, however, be used as a joint water supply and limit the amount of fresh water used.

7.81 Fresh Water Systems

Sometimes the quality of fresh water delivered to various parts of the treatment plant may be questionable, especially if the source of water is a well at the plant site. If your laboratory tests indicate a high coliform count and the water is to be used for drinking water, disinfection may be required. A high count can result from contaminated water lines either through cross connections of water systems or from old piping systems. Fresh water should be tested periodically to determine that it is satisfactory. A monthly testing program should be adequate for most plants. If a high coliform count is detected, closer intervals of testing should be conducted.

One method of water disinfection is accomplished by passing water through a two-layered quartz tube. Inside the tube is a high intensity ultra-violet lamp. As water passes through the tube at a pre-determined flow rate, the ultra-violet light kills any pathogenic organisms present. This system is of relatively low cost and can be easily installed. Chlorination may also meet your needs to provide a safe water supply. Consult with chlorinator manufacturers to match equipment with your needs.

Another method of providing safe drinking water is to purchase bottled water. This is the safest method of providing a source of drinking water in treatment plants.

7.82 Types of Hydro-pneumatic Systems

There are three basic types of hydro-pneumatic water systems. Standard air-cushion, add-air, and vent-air. The water system consists of a turbine pump and water tank with the necessary pressure switches, probes, or floats that control the tank pressure and water heights.

7.820 Standard Air-Cushion

In this system, the on/off operation of the pump is controlled by pressure alone. When the empty tank is filled, the air entrapped in the tank is compressed. The pump continues to pump until the air is compressed to a specific pressure. (At this point let us use 60 psi or 4.2 kg/sq cm.) A pressure switch that controls electric power to the motor control relay opens when the specified maximum pressure is reached.

As water is used from the tank, the water level and air-cushion pressure decrease to a pre-determined point (20 psi or 1.4 kg/sq cm). The pressure switch closes at this minimum point and starts the pump to complete the cycle. The type of switch used in this case is a differential-pressure switch. The on and off points can be adjusted to provide maximum/minimum pressures. Sometimes two independent switches are used.

As long as there is an adequate air cushion, the system works quite well. Over a period of time, the air that forms the cushion is gradually absorbed by the water in the tank. Without an adequate cushion, the pump cycles on and off at short intervals. The tank has more water and less air. To correct this problem it is necessary to empty the tank completely, thereby replenishing the air in the tank.

7.821 Add-air System

One form of add-air system uses an air charger to maintain proper pressure and level in hydro-pneumatic tanks. The air charger is connected at approximately one-half the tank height, with a tube leading to the pump suction. The air charger works in conjunction with the pump to maintain an air cushion.

When the pump starts, a low pressure area is created at the pump suction. The pressure in the tank is greater than that at the pump suction and water flows through the charger venturi.

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[9] *Cross Connection. A connection between drinking (potable) water and an unsafe water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.*

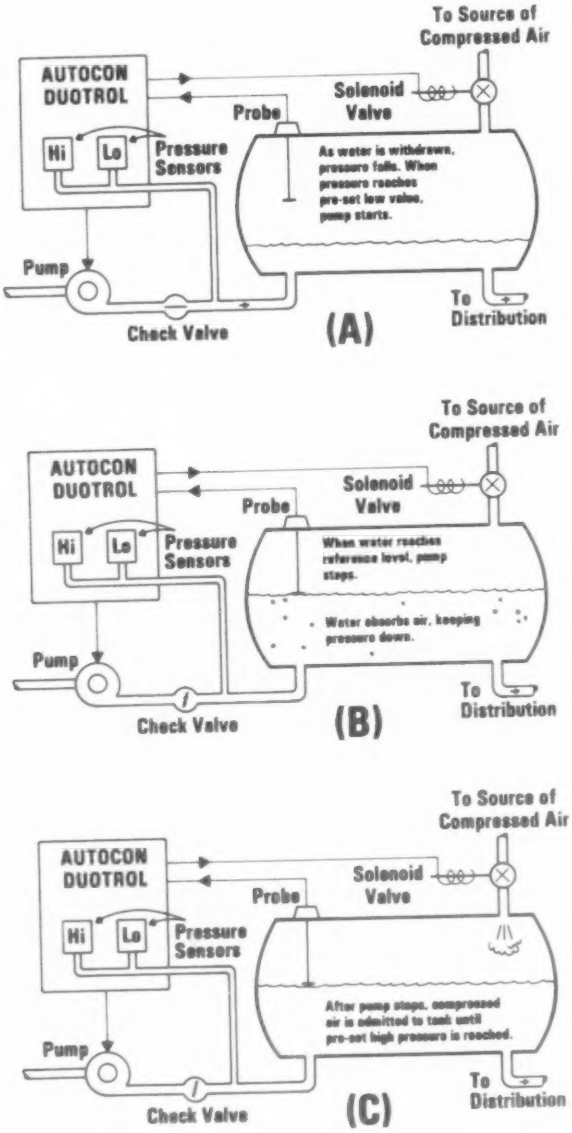

To Source of Compressed Air
AUTOCON DUOTROL
Solenoid Valve
Probe
Hi
Lo
Pressure Sensors
As water is withdrawn, pressure falls. When pressure reaches pre-set low value, pump starts.
Pump
Check Valve
To Distribution
(A)
To Source of Compressed Air
AUTOCON DUOTROL
Solenoid Valve
Probe
Hi
Lo
Pressure Sensors
When water reaches reference level, pump stops.
Water absorbs air, keeping pressure down.
Pump
Check Valve
To Distribution
(B)
To Source of Compressed Air
AUTOCON DUOTROL
Solenoid Valve
Probe
Hi
Lo
Pressure Sensors
After pump stops, compressed air is admitted to tank until pre-set high pressure is reached.
Pump
Check Valve
To Distribution
(C)

Fig. 7.39 Add-air system

(Permission of Autocon Industries, Inc., Plymouth, Minnesota)

A partial vacuum results and air is drawn through the air inlet valve into the charger body. A deflector causes the water to flow down the walls of the charger and the water and air are separated. As air accumulates in the charger, the water level decreases until a float valve closes. This stops the water flow from the tank to the pump suction. If the valve failed to close, the pump would draw air and become air-bound.

With the valve closed, the air in the charger is compressed to the same pressure as in the tank and remains so until the pump stops. When the pump stops, the pressure at the pump suction becomes equal to the tank pressure. The float in the charger opens and water flows from the tank into the pump. Air that was accumulated in the charger is forced out and into the pressure tank. Each time the pump goes through its on/off cycle the charging action is repeated. This is repeated until the water level in the tank is below the charger tank inlet. When the water level rises above the inlet, it automatically begins to replenish the air cushion.

Another method to add air to a water tank is from a compressor (Fig. 7.39). The compressor can be an integral part of the system or air can be supplied through a solenoid and connected to the "plant air" system. The controlling device for water tank level is a probe in conjunction with a pressure switch. When the pressure in the tank reaches its low level point, the pressure switch closes and starts the pump. The pump continues to operate until the water level reaches the high level probe. A time delay insures that the level is well up on the probe. A circuit is completed to the "off/pump" relay and "add-air" relay. If the pressure in the tank is not at its proper level, the air solenoid opens and adds air as needed.

As long as the add-air relay is closed, air will be added to compensate for decreasing pressure caused by water withdrawal. After the water level recedes from the probe, the "add-air" relay opens and will not allow external air to be added. The water level and tank pressure decrease until the low pressure setting is reached and the pump cycle starts again.

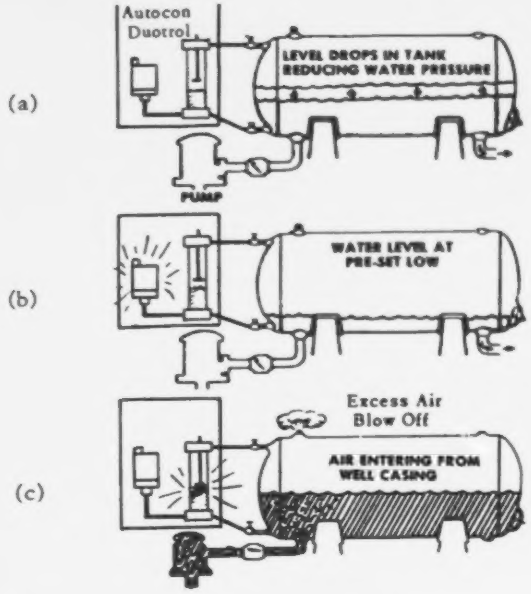
7.822 Vent-air System

The vent-air system is used to prevent air binding when a large amount of air is trapped in the water being pumped into the pressure tank. This is quite common when a deep well pump is used. One type of pump control (Fig. 7.40) is accomplished with a probe and pressure switch similar to the "add-air" system. When the tank pressure reaches its low level, the pressure switch closes and the pump starts. The pump continues to run until the water level reaches the "pump/off" probe. Any excessive air that has built up in the tank is vented through a pressure relief valve at the top of the tank. The relief valve can be adjusted to obtain optimum operating pressure. The cycle is completed when the level reaches the low pressure "pump/on" point.

A second type of control is illustrated in Figure 7.40. The control system functions as described by notations in the cross-sectional drawings of the hydro-pneumatic tank.

The three previously mentioned systems should provide nearly trouble-free operation for many years. Regular maintenance is required on the turbine pump and motor, however. The motor bearings should be lubricated on an annual basis if the motors are subject to intermittent operation. Pump packing should be checked monthly and adjusted as needed to prevent leakage around the pump shaft. The standard air-cushion system will require periodic emptying of the tank to replace the air-cushion. Problems are infrequent in the air-charging add-air system. However, the float may stick and cause the pump to become air-bound. If this is a recurring problem, replacement of the air charger is usually necessary.

In the system where a probe is used, it often becomes corroded and becomes a poor conductor of electricity. This allows the tank to fill to increasingly high levels. Remove the probe and clean with steel wool. New teflon-coated probes can alleviate this problem also.



(continued on next page)

Fig. 7.40 Vent-air system
(Permission of Autocon Industries, Inc., Plymouth, Minnesota)

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 547.

7.8A What are the two separate water systems in a wastewater treatment plant?

7.8B List the possible sources of fresh or potable water for a wastewater treatment plant.

7.8C What is a hydro-pneumatic water system?

7.83 Backflow Prevention

7.830 Need for Backflow Prevention

The reason for backflow prevention is to prevent potentially contaminated water from contaminating the potable water system. Where fresh water is used for pump packing or seal cooling, there is a possibility of the pump developing a higher water pressure than that supplied by the water system. Therefore, it is essential to have some type of device to check the backflow of coolant liquid.

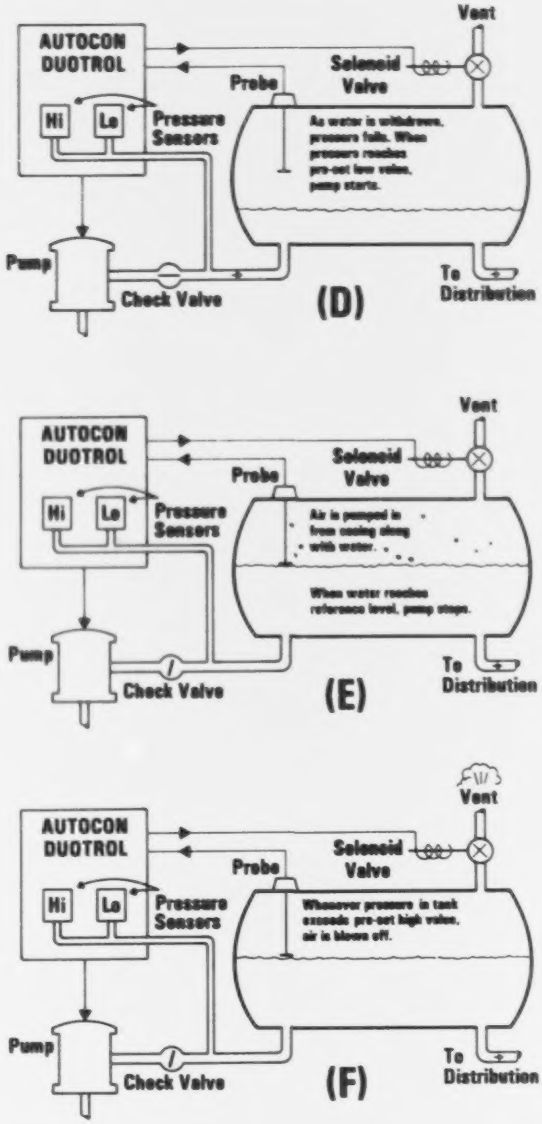

AUTOCON DUOTROL
Hi
Lo
Pressure Sensors
Probe
Solenoid Valve
Vent
As water is withdrawn, pressure falls. When pressure reaches pre-set low value, pump starts.
Pump
Check Valve
To Distribution
(D)
AUTOCON DUOTROL
Hi
Lo
Pressure Sensors
Probe
Solenoid Valve
Vent
Air is pumped in from casing along with water.
When water reaches reference level, pump stops.
Pump
Check Valve
To Distribution
(E)
AUTOCON DUOTROL
Hi
Lo
Pressure Sensors
Probe
Solenoid Valve
Vent
Whenever pressure in tank exceeds pre-set high value, air is blown off.
Pump
Check Valve
To Distribution
(F)

Fig. 7.40 Vent-air system (continued)
(Permission of Autocon Industries, Inc., Plymouth, Minnesota)

7.831 Devices

AIR GAP.[10] Where there is a possibility of connecting a municipal water system to a contaminating source, an air gap between the two systems is required. The air gap between the tank water level and the discharge of the control valve should be at least six inches (15 cm). This eliminates any possible chance of contact between the systems.

CHECK VALVE (refer to Section 7.225, "Check Valves"). The check valve prevents backflow by a mechanical means. As long as the flow is in the direction of the check and at a pressure greater than the opposing pressure, water will flow. If at some point those characteristics change, the checking device (clapper, ball, disc) will close and seat; thus preventing a reversal of flow. Most regulatory agencies require greater protection than what is provided by a simple check valve that could become stuck in the open position. Consult your local health codes before making any potential cross connections.

Checking devices must be inspected regularly to determine that they are functioning properly. Where the valve is used in a cooling system for a pump, it should be inspected at least semi-annually. Usually a pressure regulator, with strainer, is used ahead of the check. If heavy sedimentation is apparent, the time interval for inspecting the check valve should be more frequent.

ANTI-SIPHON VALVE. This valve is most commonly found in irrigation systems. In the event that a lawn becomes flooded, it will not allow the water to siphon back into the fresh water system. Municipal water departments have a requirement that anti-siphon valves be installed in irrigation systems.

When using water other than fresh No. 1 water (potable or drinking water), an anti-siphon valve will prevent flow reversal which may cause pumps to run backwards or flooding of the pump water supply.

7.84 Reclaimed Water

Due to the emphasis on water conservation and knowing that water is a depletable resource, there has been continued research in the use of reclaimed wastewater treatment plant effluent. Most of us in this field have been reclaiming a small portion of our effluent to be used for in-plant purposes for years. Because of the possibility of contamination or the spread of diseases, it is important that the reclaimed water be chlorinated. Some localities have approved the use of No. 2 water (reclaimed water that is not suitable or approved for drinking) for irrigation and many treatment plants use it for the irrigation of plant grounds. Since the use of reclaimed water outside the plant has not been accepted totally, this section will concentrate on in-plant uses.

Reclaimed plant effluent can be used effectively to cool pump shaft packing and mechanical seals. Possibly the biggest drawback in this area is obtaining water that is relatively free of sediment and suspended materials. Strainers must be cleaned more often and the supply piping tends to narrow and plug, especially when small (¼-inch or 7 mm) pipes are used. A spray of reclaimed water can control foaming on aeration tanks. Once again, the spray nozzles become plugged frequently.

The quality of the effluent and the form of filtration or screening used both affect the potential uses of reclaimed effluent. Do not use hoses on a reclaim water system and then on a fresh water system. One way to keep them separate is to use two different hose sizes and hose bibs. Test reclaimed water and ensure a low coliform count. If the count is high, increase chlorine dosage. Post signs at reclaimed water hose stations (DO NOT DRINK — CONTAMINATED WATER). Although it is good for area washdown, make sure that fellow employees wash exposed body parts thoroughly after coming into contact with reclaimed water.

Do not use this water for boiler make up water. The contaminants in the water will adversely affect the boiler system. Problems include plugged valves, corroded water jackets, and excessive sludge buildup.

One important application of reclaimed water is conveying water with a high concentration of chlorine to the dosage point for effluent chlorination. Reclaimed water may be used as a dilution or washing means in sludge dewatering systems. Use reclaimed water when it will work for a particular application, but remember its limitations. Do not inter-connect reclaimed and fresh water systems (cross connection).

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 547.

7.8D List three backflow prevention devices.

7.8E What is an "air gap"?

7.8F List five in-plant uses of reclaimed wastewater.

7.9 GROUNDS UPKEEP AND MAINTENANCE

7.90 Need for Good Appearance

One area of need that probably has not been given adequate attention in the past is general plant grounds maintenance and appearance. Since this topic covers a number of areas, this section will highlight a few of these points. Many people judge your performance on the basis of the appearance of your plant. A pleasant-appearing plant is as valuable as a good neighbor and an important part of an effective public relations and education program.

7.91 Yard Lighting

There are a couple of objectives to be met when yard or area lighting is concerned:

1. Provide adequate illumination for work being performed;
2. Provide energy-efficient lighting (greatest illumination per watt of power expended); and
3. Install fixtures that require minimal maintenance.

A number of changes have been made over the years to meet our changing lighting needs. With power costs escalating at a rapid rate, it is important that we efficiently use all power consumed. The standard incandescent light bulb, while being cheap to produce, does not convert energy to light economically. An incandescent bulb will provide approximately 18 lumens per watt. (Lumen. The unit of luminous flux. The luminous flux emitted from one international candle.) The common fluorescent will provide almost 80 lumens per watt.

Most of the new yard lighting systems use either mercury vapor or high pressure sodium (HPS) lights. The main reason is a greater amount of illumination per watt expended. The "off-yellow" lights that you see being used along streets are HPS. In this area the monochromatic light developed is not objectionable. The advantage to HPS is that it will develop 80 percent more lumens than mercury vapor (MV) (95 lumens per watt). HPS lights can cut illumination costs by one-half. If the light produced by HPS does not fit your needs, mercury vapor lights are very effective. Average lumens per watt output is 42. If your plant is thinking of expanding, or if your yard lighting power costs are higher than you would like, perhaps some of the new innovations in lighting would be the answer.

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[10] *Air Gap. An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the drinking water.*

In terms of maintenance, yard lighting is minimal. When it is necessary to replace fixture lamps, use a lighting scaffold or a boom truck with bucket. Make sure the power is off and locked out before starting. Inspect for a loose or broken socket, damaged reflectors, loose electrical connections, corroded conduits and fittings, and clean the lighting diffusers. If the fixture uses a photoelectric cell, turn on the power and place a shop towel over it. This should initiate power to the lamp ballast. If the fixture doesn't light, replace the photo cell. With a new lamp and cell, it should light. Do not attempt additional troubleshooting or repair unless you are qualified to do so. Usually this maintenance is carried out by an electrician. Electricians know how to protect themselves and others as they solve electrical and lighting problems.

7.92 Enclosures

With respect to enclosures, it is necessary that we use them as a first line of defense against intrusion. A six-foot (1.8 m) high cyclone, chain-link fence with barbed wire strands along its top looks formidable to a casual eye. We must control the access to our facilities. We can ill afford to have the public wander through our plants. We must protect the public from possible injury as well as protect our investment in buildings and equipment from theft and vandalism.

There are security systems that can add to the effectiveness of the fence. Some fences are wired to alarms that are sensitive to vibration that could represent an intruder. Gates can use magnetic switches that activate if the gate is opened without first turning off the alarm switch. An infra-red light beam, having a transmitter and receiver, can be focused along the perimeter or outside of the property. An interruption of the beam will activate an alarm. Since gateways are the natural entrance to the plant, they may be the main point of entrance. There are a number of electronic gate activators to control access. Some use a plastic card, similar to a credit card, or a digital number sequence that can be changed at random, or a radio signal to operate the gate.

Regardless of what we do, we can only keep the honest person honest. Anyone intent on obtaining access, will. What we can do is keep the enclosure in good repair, lock all gates that are not in use, and control the keys that lock them. In terms of maintenance, the gate causes the most problems. Gate hinges should be kept well oiled and the cross connection bolts should be adjusted as needed to prevent the gate from dragging.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 547.

7.9A List three objectives of an effective yard lighting system.

7.9B What items would you consider when maintaining a yard lighting system?

7.9C What is the purpose of enclosures?

7.9D How would you maintain a treatment plant gate?

7.93 Roadways and Walkways

Asphalt paving makes up the majority of plant roadways. There are a few things you can do to make asphalt paving last a long time. The extent of time that asphalt paving will serve you was determined greatly by the contractor who installed it. If you can answer "yes" to the following questions, then you have a good paving installation to maintain.

1. Was the soil stabilized and adequate subgrade material used?
2. Was the asphalt mix designed for its application?
3. Was the temperature of the mix within specifications when laid (a minimum of 235 degrees F (113°C) for asphaltic mixtures)? and
4. Was the asphalt properly rolled and compacted?

If the subgrade material was not adequate and the asphalt mix not designed for your use, it will break up. You can, however, control the routing of heavy trucks and equipment to specific areas. When asphaltic paving is laid, it must be hotter than 235 degrees F (113°C) to insure proper laying. If the mix did not contain the proper proportions of aggregate, oil, and asphalt, it will not adhere or stick together properly. Even if the asphalt is of designed thickness, improper compaction can greatly reduce its effective life span. The most signficiant shortcoming is low cohesion of the materials used. This causes an open porous texture that is susceptible to the entrance of water and air. Water will enter the pores of the mix and, as tires pass over it, the water will be forced under pressure through the voids of the asphalt. This can result in loss of bond and the paving will ravel. Air can enter poorly compacted asphalt paving and cause rapid oxidation. This will increase the brittleness of the paving.

Asphalt paving loses a certain amount of oils that must be replaced. Resealing should be done when this is first noticed. A thin layer of asphalt oil is evenly spread over the paving. A small amount of sand is usually added to prevent tracking of the oil. If you have low spots in the paving where water can accumulate, have the spots repaired. Standing water invites unwanted problems. That is why yard drainage must be adequate.

Concrete walkways are also controlled to some extent by the contractor who installed them. Here are a few ways we can maintain walkways. Keep the sidewalk free from algae. A solution of soap and chlorine (clorox) will remove algae with a small amount of scrubbing and prevent immediate algae regrowth. A slippery walk can be etched with muriatic acid and water. One part acid to ten parts water will do the job. Do not try this procedure unless you have had experience doing it. A smooth concrete finish can be lightly sand blasted to roughen it up to reduce slipperiness. There are also non-skid coatings that can be applied to the concrete. In most instances, this will be the preferred solution since they can be easily applied by plant personnel.

Do not allow weeds or grass to grow in the cracks of the concrete. Just as a tree root can split a large rock, weed roots can cause the same effect. Be on the lookout for concrete sections that have risen, dropped, or tilted. Eliminate this tripping hazard by replacing that section of walkway.

All sidewalks should be kept clear. If you must set an object down, set if off to the side. Water hoses are a potential tripping hazard when left lying about. Keep them rolled and on their racks. Since water is our process product, be aware of it. Water and water spray on concrete is a link in the chain of events that lead to one of our industry's most common accidents — slips and resultant falls.

7.94 Landscape

7.940 Purpose of Landscaping

Landscaping enhances the appearance of any plant site. Because our treatment facilities have a certain stigma, it is important that we enhance the surrounding grounds. When visitors enter a wastewater treatment plant, many may have preconceived thoughts. A well manicured lawn, trimmed shrubs, along with a variety of ground cover will provide a positive "first impression." Take pride in your treatment plant and it will be apparent to all who enter your gates.

When a plant is designed and built, landscaping is a very important part of the construction. Usually landscaping is well done by professionals. Our responsibility is to maintain that investment and appearance.

The following paragraphs will shed light on how to best achieve adequate landscape appearance and yard maintenance.

7.941 Irrigating

If your plant is one of many that enjoy a beautiful green lawn, you know the importance of proper watering and water coverage. If your sprinkler system was installed by a competent private contractor, chances are it was engineered to provide adequate lawn coverage. A good indication that coverage is inadequate is a non-uniform appearance of the lawn. The sprinkler drops the greatest amount of water near the head and very little at its outer limits. The small amount of water doesn't penetrate very deep and the grass roots are very shallow. The weak grass allows for weeds such as dandelion, sorrel, and plantain, that can take less water than typical lawn grasses. On the other hand, spots that are subject to too much water invite sedge, crabgrass, chickweed, and annual blue grass. The best answer to unequal water distribution is to alternate the sprinklers and wetting pattern.

When and how often do you water? Grass shows its need for water first by loss of resilience. When you walk on grass needing water, there is no spring back. Next, the color changes from a fresh green to a dull gray-green. The grass tops turn brown and die in the next stage. Ideally you should water before the no-spring back sign begins. After living with a lawn for a while you can sense that timing. Deep watering once a week is recommended. This causes plants to root deeper. As water is drawn from the soil by the grass roots, more air enters the ground and a better growth environment is created. Long slow watering will allow for good penetration. A three-hour application is quite common. Depending upon the type of soil you have, water penetration will be approximately one inch during the proper watering period.

Some of the reasons for not using light, frequent waterings are:

1. Greater water use,
2. Shallow rooting of grass,
3. Encouragement of shallow-rooted weeds,
4. Greater soil compaction, and
5. Rapid buildup of salinity due to lack of leaching.

7.942 Controlling Weeds

If we always grew only what we sowed originally in a lawn, the task of keeping a lawn would be easier. The trouble is that soils are generally full of dormant weed seeds waiting for the right conditions to germinate. Weed seed is also present in lawn seed mixtures to a small degree. Wind and birds help bring in new seeds. We will always have weeds. The question is how to get rid of them. There is a wide variety of chemical weed killers (herbicides) available. Most herbicides are selective and control a specific type of weed. They fall into two classes, broadleaf and grassy.

The term "broadleaf" is used to describe non-grassy weeds. A few of the familiar ones are: dandelion, curly dock, chickweed, bur clover, oxalis, knotweed, and English daisy. The hormone-type weed killers such as 2,4D and 2,4,5-TP are the best known of the herbicides. They kill broadleaf plants by speeding growth so the plants literally grow themselves to death. Depending on the species, weeds may require one to four treatments to obtain a good kill. This type of chemical is absorbed by the leaves and carried through the system to the roots. Both tops and roots are killed. Weeds treated with chemicals show curled and twisted stems in the first stage. Finally, the roots are expanded and ruptured and the entire plant dies. Select a weed killer that kills the entire plant. Burning the leaf may indicate a kill, but a vigorous root system could survive and cause regrowth.

The grassy weeds are also all too familiar: Burmuda grass, quackgrass, nutgrass, velvet grass, and orchard grass. One thing to remember if you are applying a chemical to control grassy weeds: it can also kill the lawn grasses. Therefore, it is best to do controlled spot killing in the affected areas. Spot application of dalapon or amitrol will generally take care of local grasses. Be sure to follow label directions closely. If your lawn is overcome by grassy weeds, it may be necessary to use a soil fumigant. The fumigant chemically kills almost everything in the soil and leaves it sterile. Three commonly used fumigants are Vapam, Mylone, and calcium cyanamid. If applying the chemical yourself, follow directions closely.

If you are faced with a large weed-control problem, hire a professional. There are commercial companies who are knowledgeable and capable of handling your problem. When faced with weeds that grow along chain link fences or dirt around buildings, a light application of diesel fuel will do the trick. All you need is a handheld pressure sprayer to insure adequate coverage. Do your spraying on calm days without wind. The objective is to kill only the selected weeds and grasses. When the wind kicks up, discontinue application until the wind dies down again.

7.943 Fertilizing

Grass has a continual need for nitrogen. Nature does a poor job of supplying that nutrient in quantities necessary to keep plants growing thick, green, and dense. If a lawn turns yellow or pale green or if grass becomes thin and weeds come in, it is probably an indication that nitrogen is needed. If you apply a fertilizer containing nitrogen and the lawn does not respond, then suspect other trouble such as disease, lack of air, or grubs and other larvae. The use of reclaimed water for lawn irrigation substantially reduces the need for fertilizers.

When you purchase a fertilizer, the three-number formula such as 6-4-2 indicates first the percentage of nitrogen, second the percentage of phosphorus, and third the percentage of potassium. Consider the phosphorus and potassium as a bonus to lawn feeding. The ever-important nitrogen comes in several forms. Some types are slow acting and may take a number of weeks or months for the nitrogen to be fully used by the lawn. Other forms are fast acting and immediate results can be seen in just a few days. When reading labels, remember not all organics are slow acting and not all inorganics are fast acting. The rate of availability grades down from immediate to gradual over a period of months.

Here are the meanings of the words on the fertilizer label that refer to nitrogen:

NITRATE. The form of nitrogen that is available to the plant as is, regardless of temperatures.

AMMONICAL OR AMMONIC. Available to plants when converted by bacteria to nitrate. Speed of conversion depends upon soil temperatures.

ORGANIC. Describes sludge, cottonseed meal, and any other materials that must first be broken down by bacteria.

UREA. A synthetic organic that water and the enzyme urease change immediately to inorganic ammonia. The ammonia is then converted to nitrate.

UREA FORM OF UREA FORMALDEHYDE. A nitrogen fertilizer that has been specially compounded for slow release.

How often do you feed a lawn? The color of the grass can show nitrogen need. An easy method used to determine need is the number of times per week or month that the lawn needs cutting. At the start, if cuttings were done every five to eight days and then extended to eight to fourteen days, more fertilizer is needed. Depending on the fertility of the lawn soil, grass will show a loss of color in four to eight weeks after fertilization. Thus, the feed-when-it-needs-it method could require fertilizer from three to twelve times a year. If fertilizing is a problem, then feed the lawn adequately in the spring and fall. This procedure may not be quite as effective as desirable, but the lawn should do quite well.

How much do I feed the lawn? A rule of thumb is one pound actual nitrogen for every 1,000 square feet of lawn per month (this applies only to the growing months). To figure actual nitrogen needs, take the percentage stated on the label times the weight of the fertilizer. For example a 20-pound bag (it could be liquid) containing 15 percent nitrogen will yield approximately 3 pounds of nitrogen or enough to feed 3,000 square feet for a month (20 pounds times 0.15 equals 3. pounds nitrogen).

Application of fertilizer should be distributed as evenly a possible. The most effective applicator is a hopper spreader. Four common mistakes when using the spreader are:

1. You cannot turn an open hopper inside a previous turn. The square corner will allow for excessive fertilizer application at that point.
2. You cannot stop and start with the hopper open. Walking at an unsteady pace will do the same thing.
3. Do not overlap with fertilizer.
4. Do not make 180-degree turns. Since one wheel is still driving the sifter, dispersal on the turn is very erratic.

After applying fertilizer, water the lawn heavily. Most fertilizers require a soaking to get the action started. This also prevents burning the grass blades.

7.944 Mowing and Pruning

Mowing and pruning are very important. Lawns must be mowed and edged at regular intervals to maintain their appearance. Trees and shrubs should be kept pruned so they won't interfere with the operation and maintenance of the plant, as well as to appear neat.

7.95 Surface Water Drainage

Depending on the location of your plant, drainage of storm water runoff and other surface water runoff can be very important. No one wants unwanted water running into buildings or flooding roadways and walkways. Provisions to handle this water should have been made when the plant was designed. Maintenance of these facilities requires keeping all curb drains and drop inlets free of leaves and other debris. Also, the storm drain lines must be clear and ready to handle any runoff. Sump pumps in the drainage system should be included in a regular preventive maintenance program, depending on the type, size, and frequency of use of the pumps.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 547 and 548.

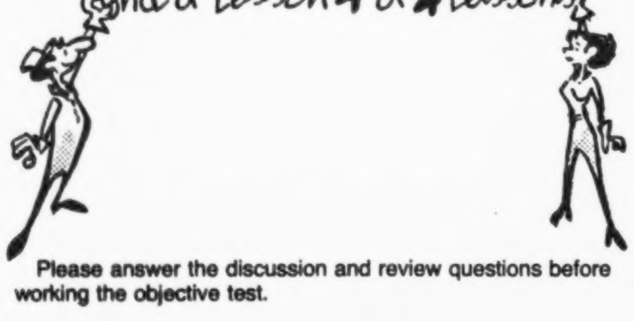
7.9E What factors are essential to have a good paving installation?

7.9F What items would you consider in a walkway maintenance program?

7.9G How do weed seeds get in a lawn?

7.9H How could you tell if a lawn needs nitrogen?

End of Lesson 4 of 4 Lessons



Please answer the discussion and review questions before working the objective test.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 4 of 4 Lessons)

Chapter 7. MAINTENANCE

Write your answers to these questions in your notebook before continuing. The question numbering continues from Lesson 3.

19. How can water from a well at a treatment plant be disinfected?
20. What is the purpose of backflow prevention devices?
21. Why must reclaimed wastewater be chlorinated?
22. How important is the appearance of your treatment plant?
23. What safety precautions should be taken when maintaining yard lighting fixture lamps?
24. How would you maintain the landscape around your treatment plant?

SUGGESTED ANSWERS

Chapter 7. MAINTENANCE

Answers to questions on page 471.

7.0A Support systems equipment includes portable pumps, pipes, valves and fittings. Facilities include auxiliary electrical equipment, gasoline engines, diesel engines, heating, ventilating, air conditioning and plant air and water systems. Plant appearance also is important and includes control of drainage runoff, lighting, walkways, roadways, and landscaping.

7.1A Portable centrifugal pumps are often referred to as trash pumps because the water being pumped is not clean and many have solids of various sizes suspended in the water.

7.1B The suction hose has a strainer on the end to prevent pulling rocks and debris into the pump to avoid damaging the pump or plugging the hoses or pipes.

7.1C When operating a portable pump in weather that is subject to freezing, always drain the pump to prevent the freezing water from cracking the casing or binding up the pump. Before starting the pump, turn the shaft by hand to be sure it turns freely. If the impeller is frozen fast, warm the pump slowly until the ice melts.

Answers to questions on page 474.

7.1D Some of the advantages of the positive displacement diaphragm pump are as follows:

1. Self-priming if the suction lift is small;
2. When primed with water, it will pump with a suction lift up to 25 feet (7.5 meters);
3. Large particles will readily pass through the pumps; and
4. Less likely to become clogged than centrifugal pumps.

7.1E If a diaphragm pump suddenly stops pumping, remove discharge valve and clean out pump cavity.

7.1F After use, pneumatically operated diaphragm pumps should be flushed thoroughly to prevent dried sediment from obstructing valve operation. If the water pumped had large particles in it, it may be necessary to dismantle the pump to remove any remaining particles.

Answers to questions on page 478.

7.2A Galvanized pipe is subject to corrosion in an atmosphere containing hydrogen sulfide or chloride compounds (salts or chlorine).

7.2B Galvanized pipe can be protected from corrosion by (1) a protective coating of vinyl or a tar-based product, and (2) some form of cathodic protection.

7.2C Ductile iron pipe might corrode if installed in salt marshes, highly alkaline soil, waste dumps, or cinder fills.

7.2D A major limitation of concrete pipe is the ease with which the inside of the pipe corrodes in the presence of hydrogen sulfide gas.

Answers to questions on page 487.

7.2E Valves are the controlling devices placed in piping systems to stop, regulate, check, divert, or otherwise modify the flow of liquids or gases.

7.2F The five most common types of valves found in wastewater treatment facilities are gate valves, globe valves, eccentric valves, butterfly valves, and check valves.

7.2G The purpose of a check valve is to allow water to flow in one direction only.

7.2H Backflow prevention by check valves is essential in many applications to:

1. Prevent pumps from reversing when power is removed,
2. Protect water systems from being cross connected,
3. Aid in pump operation as a dampener, and
4. Insure "full pipe" operation.

7.2I Victaulic couplings are used in an area where future disassembly is anticipated. Quite often you will find them on the suction and discharge sides of pumps.

7.2J Band seals are used to join clay, soil pipe, or asbestos-cement pipe.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 490.

7.3A A qualified electrician should perform most of the necessary maintenance and repair of electrical equipment to avoid endangering lives and to avoid damage to equipment.

7.3B The purpose of a "kirk-key" system (one key is used for two locks) is to insure proper connection of standby power into your power distribution system. The commercial power system must be locked out by the use of switch gear before the standby power is connected to your power distribution system.

7.3C Battery-powered lighting units are considered better than engine-driven power sources because they are more economical. If you have a momentary power outage, the system responds without an engine-generator start-up.

7.3D If water lost from a lead-acid battery is replaced with tap water, the impurities in the water will become attached to the lead plates and shorten the life of the battery.

Answers to questions on page 492.

7.3E Electricity is transmitted at high voltage to reduce the size of transmission lines.

7.3F If outdoor transformers have exposed high voltage wires, the following precautions must be taken:

1. An eight-foot (2.4 m) high fence is required to prevent accessibility by unqualified or unauthorized persons; and
2. Signs attached to the fence must indicate "High Voltage."

7.3G The treatment plant operator must keep the exterior and surroundings of the switch gear clean.

7.3H Symptoms that a power distribution transformer may be in need of maintenance or repair include unusual noises, high or low oil levels, oil leaks or high operating temperatures.

Answers to questions on page 500.

7.4A The four strokes in a four-stroke-cycle engine are the (1) intake stroke, (2) compression stroke, (3) power stroke, and (4) exhaust stroke.

7.4B

Known		Unknown
Piston bore, in	= 3 in	Piston Displacement, cubic inches
Stroke travel, in	= 4 in	

Calculate the piston displacement in cubic inches.

$$\text{Piston Displacement, cubic inches} = \frac{\pi}{4} \times (\text{Bore, in})^2 \times \text{Stroke Travel, in}$$

$$= \frac{3.1416}{4} \times (3\text{ in})^2 \times 4\text{ in}$$

$$= 28.27\text{ cu in}$$

7.4C Two major types of valve problems are burnt valves and valve sticking

7.4D The purpose of a carburetor is to produce a mixture of fuel and air on which an engine will operate.

7.4E The purpose of a governor is to provide a constant engine speed regardless of load.

Answers to questions on page 508.

7.4F Heat is removed from the cylinders by a water cooling system. Each cylinder is surrounded with a water jacket through which the coolant (water) circulates and pulls heat from the cylinder. This is accomplished by a water pump that is belt-driven from the crankshaft.

7.4G A magneto is a self-contained device that generates and distributes electricity needed to ignite the fuel mixture in the combustion chamber.

7.4H The fuel mixture (oil and gasoline) provides lubrication for the moveable parts in the crankcase.

7.4I (1) If the fuel mixture contains too much oil, you'll have poor carburetion, poor engine performance, excessive smoke out the exhaust, and incomplete burning of the mixture.

(2) If the fuel mixture has too little oil, you'll have poor lubrication of the crankshaft, connecting rod bearings, and piston cyclinder wall. This can cause premature bearing failure and scored cylinder walls. The engine will run hot and seize up.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 528.

7.5A Gasoline is not used as a fuel in diesel engines because it would start to burn from the heat generated by compression before the piston reaches the top of the stroke.

7.5B The four basic parts of a diesel fuel system are:

1. Primary fuel filter,
2. Secondary fuel filter,
3. Fuel injection pump, and
4. Fuel injector.

7.5C The purpose of the fuel injection pump is to deliver fuel to the injector at a very high pressure.

Answers to questions on page 529.

7.6A Common items that are similar for almost all gas-fired hot water boilers include:

1. Gas system,
2. Water system,
3. Control switches, and
4. Boiler maintenance.

7.6B The automatic gas valve is controlled by the operating thermostat.

7.6C Boilers should be drained on an annual basis to remove sludge from the bottom of the boiler.

7.6D Boiler feed water must be tested for hardness because hard water causes scale to build up inside the boiler.

Answers to questions on page 531.

7.6E A plenum chamber is an air chamber maintained under pressure to serve one or more air distribution ducts.

7.6F The four classes of centrifugal blowers include:

1. Forward curve,
2. Backward inclined,
3. Radial blade, and
4. In-line (tubular centrifugal fan).

7.6G Refrigeration is the process of transferring heat from one place to another.

7.6H If an air conditioner runs but fails to cool, some of the refrigerant charge may have been lost.

Answers to questions on page 533.

7.7A The two most common types of air compressors in use today are the rotary and reciprocating types.

7.7B The type oil recommended for high volume and pressure units is a non-detergent straight mineral oil (turbine or hydraulic type), which is solvent refined and contains rust and oxidation inhibitors and anti-foam additives. Viscosity is in the 150-200 Saybolt universal seconds range at 100°F (38°C).

7.7C The following items are important considerations when purchasing a rotary compressor:

1. Rated capacity in CFM,
2. Rated operating pressure,
3. Duty cycle — intermittent or continuous,
4. Horsepower requirements, and
5. Stages.

Answers to questions on page 536.

7.7D Sticky intake valves in a reciprocating compressor will either prohibit or reduce air intake and sticky discharge valves will reduce or prevent compression.

7.7E Air fed to a compressor should be clean, cool, and dry to provide satisfactory operation.

7.7F An oil-bath type of air filter is used if the intake air contains considerable dust and other contaminants.

7.7G The major components for power air systems include:

1. Filter,
2. Pressure regulator,
3. Lubricator (not used with instrument control systems).

7.7H Outlets should be taken from the top of the main line (tees facing up) to keep moisture out.

7.7I Air system components for power tool use include a lubricator while in pneumatic control systems there is no lubricator, but an absorbent-type filter is added.

END OF ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 539.

7.8A The two separate water systems in a wastewater treatment plant are the fresh or potable water supply and the reclaimed water.

7.8B Possible sources of fresh or potable water for a wastewater treatment plant include:

1. Public domestic water supply,
2. Wells, and
3. Bottled water.

7.8C A hydro-pneumatic water system consists of a turbine pump and water tank with the necessary pressure switches, probes, or floats that control the tank pressure and water height. The air pressure over the water in the tank forces water out the taps when valves are opened.

Answers to questions on page 541.

7.8D Backflow prevention devices include:

1. Air gap,
2. Check valve, and
3. Anti-siphon valve.

7.8E An air gap is an open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back-siphonage because there is no way wastewater can reach the potable water.

7.8F In-plant uses of reclaimed wastewater include:

1. Irrigating treatment plant grounds,
2. Cooling of pump shaft packing and mechanical seals,
3. Spraying on aeration tanks to control foaming,
4. Washing down areas,
5. Diluting or washing in sludge dewatering systems, and
6. Conveying water with a high concentration of chlorine to the dosage point for effluent chlorination.

Answers to questions on page 542.

7.9A Three objectives of an effective yard or area lighting include:

1. Provide adequate illumination for work being performed;
2. Provide energy-efficient lighting (greatest illumination per watt of power expended); and
3. Install fixtures that require minimal maintenance.

7.9B Items that should be considered when maintaining a yard lighting system include inspecting for:

1. Loose or broken electrical connections,
2. Corroded conduits and fittings,
3. Damaged reflectors,
4. Dirty lighting diffusers (clean if necessary), and
5. Proper operation of photoelectric cell (if used).

7.9C The purpose of enclosures is to prevent the public from wandering through our plants. We must protect the public from possible injury as well as protect our investment in buildings and equipment from theft and vandalism.

7.9D Maintenance of a treatment plant gate consists of keeping (1) the hinges well oiled, and (2) the cross-tie bolts properly adjusted to keep the gate from dragging.

Answers to questions on page 544.

7.9E To have a good paving installation you must have:

1. Soil properly stabilized and adequate subgrade material used;
2. Asphalt mix designed for its application;
3. Temperature of mix within specifications when laid; and
4. Asphalt properly rolled and compacted.

7.9F Items that should be considered in a walkway maintenance program include:

1. Keeping walkway free from algae and other slippery materials;
2. Removing weeds and grass from cracks;
3. Correcting concrete sections that have risen, dropped or tilted; and
4. Keeping walkways clear.

7.9G Weed seeds get into a lawn from the soil, lawn seeds, birds, and the wind.

7.9H A lawn needs nitrogen if it turns yellow or pale green or if the grass becomes thin and weeds start growing.

END OF ANSWERS TO QUESTIONS IN LESSON 4.

OBJECTIVE TEST

Chapter 7. MAINTENANCE

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one answer to each question.

1. Dynamic heads are measured when a pump is not operating.
    1. True
    2. False

2. A suction lift occurs when the surface of the water to be pumped is below the center line of the pump impeller.
    1. True
    2. False

3. Centrifugal pumps cannot operate with considerable suction lift at decreasing flow rates as the water level drops in the wet well.
    1. True
    2. False

4. An advantage of mechanical seals is that they are not damaged when run dry.
    1. True
    2. False

5. Galvanized pipe is steel pipe that has been coated with zinc by an electro-chemical process.
    1. True
    2. False

6. PVC pipe is immune to nearly all types of corrosion, be it biological, chemical or electro-chemical.
    1. True
    2. False

7. An advantage of PVC pipe is that it will not deteriorate when exposed to sunlight.
    1. True
    2. False

8. Standard concrete pipe is smoother and has lower friction losses than asbestos-cement pipe.
    1. True
    2. False

9. Gate valves are commonly used to control flow.
    1. True
    2. False

10. The most practical form of emergency lighting is that provided by standby power generators.
    1. True
    2. False

11. The horsepower of a gasoline engine is inversely proportional to the volume of the piston displacement.
    1. True
    2. False

12. Diesel engines are similar to gasoline engines and may be either two- or four-cycle.
    1. True
    2. False

13. Diesel engines use spark plugs.
    1. True
    2. False

14. All organic fertilizers are slow acting and all inorganic fertilizers are fast acting.
    1. True
    2. False

15. A qualified electrician should perform most of the necessary maintenance and repair of electrical equipment.
    1. True
    2. False

16. Which of the following factors must be considered before selecting a pump?
    1. Desired pumping rate in gallons per minute
    2. Distance liquid is to be pumped
    3. Liquid and any solids to be pumped
    4. Location of pump nameplate
    5. Type of power needed

17. Suction lift is the pressure measured from the center line of the pump
    1. Down to the energy grade line.
    2. Down to the hydraulic grade line.
    3. Down to the inlet of the suction pipe.
    4. Up to the energy grade line.
    5. Up to the hydraulic grade line.

18. Proper installation of portable pumps to dewater ditches requires
    1. Long suction line to keep pump away from trench.
    2. Pump level and securely supported.
    3. Suction line sloping down to pump for priming purposes.
    4. Throttle and check valves installed in suction line.
    5. Use of elbows and fittings to keep pipe supported by ground.

19. Advantages of concrete pipe include the pipe's ability to
    1. Be installed and backfilled under any conditions.
    2. Be manufactured and installed in large sizes.
    3. Withstand external corrosion.
    4. Withstand external pressures.
    5. Withstand internal corrosion.

20. Proper selection of an emergency lighting unit for a particular location requires careful consideration of which of the following items?
    1. Costs
    2. Lighting requirements
    3. Nearness of vendor to repair failures
    4. Necessary switch gear
    5. Types of batteries

21. The keys to prolonged life of a battery are to keep the
    1. Battery fully charged.
    2. Battery operating continuously.
    3. Booster terminals connected to the battery.
    4. Electrolyte level above the cell plates.
    5. Terminals and top clean.

22. Names of engine valve parts include
    1. Bore.
    2. Face.
    3. Head.
    4. Seat.
    5. Stroke.

23. The ignition system for a gasoline engine consists of the
    1. Battery.
    2. Coil.
    3. Distributor.
    4. Filter.
    5. Thermostat.

24. Scale is an important consideration in the operation and maintenance of boilers because scale reduces
    1. Cleaning requirements.
    2. Corrosion.
    3. Efficiency.
    4. Heat transfer.
    5. Operating costs.

25. Mechanical maintenance for air conditioners includes
    1. Clearing compressor of obstructions.
    2. Cleaning or replacing filters.
    3. Lubricating bearings.
    4. Lubricating compressor.
    5. Making sure condensation drip line is not plugged.

26. If a compressor fails to operate or provide rated capacity, what could be the cause of the problem?
    1. Air cleaner, cap and/or screen clogged
    2. Air receiver safety valve malfunctioning
    3. Engine fails to develop proper RPMs
    4. Pressure regulator improperly adjusted
    5. Oil seal faulty

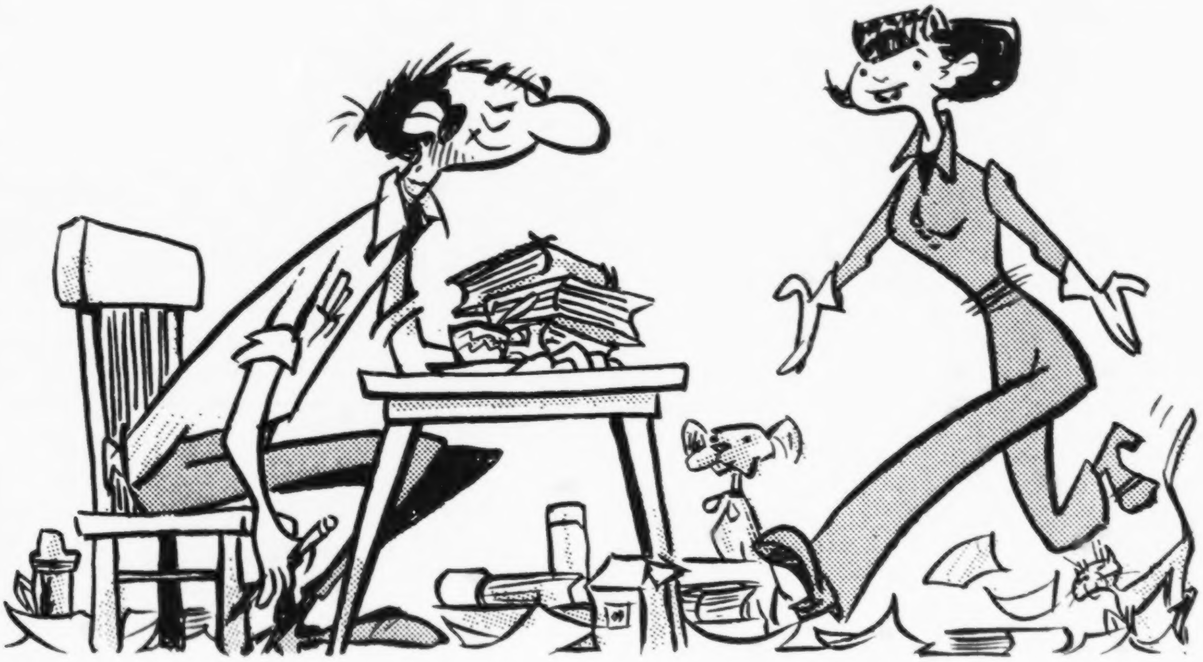
27. Which of the following items are used as checking devices in a check valve?
    1. Ball
    2. Check
    3. Clapper
    4. Disc
    5. Slapper

28. Which of the following sources of light produce the most lumens per watt?
    1. Common fluorescent light
    2. High pressure sodium light
    3. Mercury vapor light
    4. Modern light bulb
    5. Standard incandescent light bulb

END OF OBJECTIVE TEST

CONGRATULATIONS

You've worked hard and completed a very difficult program.



APPENDIX

FINAL EXAMINATION
AND
SUGGESTED ANSWERS

GLOSSARY

SUBJECT INDEX

FINAL EXAMINATION

This final examination was prepared *TO HELP YOU* review the material in this manual. The questions are divided into four types:

1. True-false,
2. Multiple choice,
3. Problems, and
4. Short answer.

To work this examination:

1. Write the answer to each question in your notebook,
2. After you have worked a group of questions (you decide how many), check your answers with the suggested answers at the end of this exam, and
3. If you missed a question and don't understand why, reread the material in the manual.

You may wish to use this examination for review purposes when preparing for civil service and certification examinations.

Since you have already completed this course, you do not have to send your answers to California State University, Sacramento.

True-False

1. Pure oxygen systems may be used to supply oxygen to any of the activated sludge process modes — conventional, step-feed, complete mix or contact stabilization.
    1. True
    2. False
2. Cold liquid oxygen (LOX) can cause skin burns.
    1. True
    2. False
3. Changes in activated sludge quality cause changes in the settling characteristics of the sludge.
    1. True
    2. False
4. The activated sludge process is controlled by attempting to achieve preconceived levels of individual variables such as MLSS, MCRT and F/M ratio.
    1. True
    2. False
5. Storage often must be provided in sludge treatment and disposal systems to accommodate differences between sludge disposal rates and sludge production rates.
    1. True
    2. False
6. Addition of alum will increase the alkalinity in the water being treated during the coagulation process.
    1. True
    2. False
7. An instrument is a device that causes changes to occur.
    1. True
    2. False
8. The scales on an indicator may be straight, curved, or circular in shape.
    1. True
    2. False
9. The headworks ventilation system must be kept operating both for the operator's safety and for minimizing the accumulation of concentrations of moist or otherwise corrosive and toxic gases.
    1. True
    2. False
10. A good sewer-use ordinance is the proper tool to provide the necessary authority to control industrial wastes.
    1. True
    2. False
11. A good sampling point is one that is easily accessible and may be located anywhere that a representative sample may be obtained.
    1. True
    2. False
12. Prompt testing of samples prevents physical, chemical and/or biological changes in the sample.
    1. True
    2. False
13. Measuring the flow from an industry is not as important as obtaining good samples.
    1. True
    2. False
14. Depending on their nature and concentration, certain foreign chemicals in drinking water may produce sudden illness, or may produce long-term "chronic" illness which is not diagnosed for years, but which may have severe effects.
    1. True
    2. False

15. One of the most effective means of treating pulp and paper wastes is the recovery of materials.
    1. True
    2. False

16. Due to the seasonality of production and the characteristic nutrient deficiency in fruit and vegetable processing water, biological treatment is highly effective.
    1. True
    2. False

17. The dissolved air flotation system is based on the principle that the solubility of gases in a solution decreases as the pressure on the solution increases.
    1. True
    2. False

18. When attempting to correct a dissolved air flotation thickener process problem, the operator must not change more than one variable at a time.
    1. True
    2. False

19. Screens take up less space than clarifiers and are not so much affected in performance by changes in flow rate or temperature.
    1. True
    2. False

20. One operational strategy for operating screens is to place the number of screens on line needed to handle the flows and solids to be treated.
    1. True
    2. False

21. The rate of rusting or corrosion increases in rainwater and increases even more in saltwater.
    1. True
    2. False

22. Short-circuiting is not caused by differences in water density due to different temperatures existing at the surface and the bottom of the clarifier.
    1. True
    2. False

23. The purpose of activated carbon adsorption in wastewater treatment is to remove suspended solids from the effluent of the treatment plant.
    1. True
    2. False

24. Suction lift is the positive pressure on the suction side of the pump.
    1. True
    2. False

25. If the priming water for a pump contains soaps or detergents, problems can develop if a high suction lift exists.
    1. True
    2. False

Multiple Choice

1. Organic wastes are in the effluents of which of the following industries?
    1. Dairy
    2. Fruit processing
    3. Gravel washing
    4. Paper
    5. Petroleum

2. Cryogenic oxygen plants are usually shut down ____________ for maintenance.
    1. Once every six months
    2. Once every year
    3. Once every two years
    4. Once every five years
    5. Once every ten years

3. Return activated sludge (RAS) flow rate may be adjusted or controlled by which of the following techniques?
    1. Food/Microorganisms Ratio
    2. Mean Cell Residence Time (MCRT)
    3. Monitoring the depth of the sludge blanket
    4. SVI approach
    5. Settleability approach

4. Which of the following items could indicate that a high organic waste load has reached an activated sludge process?
    1. Decrease in DO residual in aeration tank
    2. Decrease in nutrients in effluent from secondary clarifier
    3. Decrease in turbidity in effluent from secondary clarifier
    4. Increase in DO residual in aeration tank
    5. Increase in turbidity in effluent from secondary clarifier

5. Major factors affecting biological nutrification include
    1. Dissolved oxygen.
    2. Nitrogenous food.
    3. pH.
    4. Toxic materials.
    5. Wastewater temperature.

6. If no coagulation occurs in a chemical treatment process, which of the following items should be inspected?
    1. Actual feeder output by catching a timed sample
    2. Applied water for a significant change
    3. Feed chemical strength
    4. Skimmer arms
    5. Tank drain valve

7. Abnormal operating conditions for microscreens include
    1. High flows.
    2. High pH levels.
    3. Low applied water flows.
    4. Low pH flows.
    5. Toxic wastes.

8. Which of the following items should be inspected or checked before starting a chemical feeder?
   1. Direction and rotation of moving parts in motors
   2. Operation of control lights on control panel
   3. Operation of safety lock-out switches
   4. Proper voltage
   5. Size of overload protection

9. Which of the following items would you check if laboratory tests indicated high turbidity and suspended solids in the effluent of a gravity filter?
   1. Check for excessive head loss
   2. Determine filter aid dosages
   3. Examine backwash cycle for complete wash
   4. Inspect for damaged bed due to backwashing
   5. Look for fluctuating flows that could cause breakthrough

10. Which method or device should you use to measure the diameter of a replacement pump shaft?
    1. Engineer's scale
    2. Metallic tape
    3. Micrometer
    4. Ruler
    5. Surveyor's chain

11. The primary element in a control system is also called a
    1. Controller.
    2. Receiver.
    3. Recorder.
    4. Sensor.
    5. Transmitter.

12. Sludge blanket depths may be measured by the use of
    1. Bubbler tubes.
    2. Floats connected to cables and pulleys.
    3. A hose and an aspirator.
    4. Pressure gages.
    5. Ultrasonic transmitters and receivers.

13. Which of the following factors are usually measured by air compressor vibration sensing devices?
    1. Acceleration
    2. Displacement
    3. Flow
    4. Time
    5. Velocity

14. Why should industrial wastes discharged into a collection system be monitored?
    1. To impose fines on industries
    2. To prevent shock loads from upsetting wastewater treatment processes
    3. To protect operators of wastewater collection systems and treatment plants from hazardous and toxic substances
    4. To protect the public by preventing toxic industrial wastes from reaching drinking water supplies
    5. To protect wastewater collection and treatment facilities from corrosive and other harmful substances

15. Flows should be measured from an industry in order to
    1. Calculate the quantities of pollutants discharged.
    2. Check compliance with pretreatment requirements.
    3. Determine which flow meter works best.
    4. Measure toxic gases released.
    5. Prepare accurate and equitable billing calculations.

16. The dissolved air flotation process may be used for
    1. Coagulation.
    2. Flocculation.
    3. Solids recovery.
    4. Wastewater treatment.
    5. Water recovery.

17. What could be the cause of wastewater not flowing through a microscreen?
    1. Aperture size too large
    2. Inadequate cleaning
    3. Inadequate depth of water
    4. No wastewater flowing to screen
    5. Overload conditions, too many solids

18. Hazardous fumes, gases or conditions that might be encountered in a confined space include
    1. Gasoline vapors.
    2. Hydrogen sulfide.
    3. Lack of oxygen.
    4. Solvent fumes.
    5. Toxic gases.

19. Iron compounds used as coagulants are
    1. A potential source of iron in the effluent.
    2. Capable of increasing the BOD in the effluent.
    3. Corrosive.
    4. Difficult to dissolve in water.
    5. Potentially dangerous if they (ferric sulfate or copperas) come in contact with quicklime.

20. Daily operational procedures for an activated carbon process include
    1. Backflushing of fine-mesh screens.
    2. Measuring BOD removal efficiencies.
    3. Measuring COD removal efficiencies.
    4. Measuring effluent turbidity.
    5. Measuring level of carbon remaining in reactor.

21. Which of the following items are possible causes of a portable pump not priming?
    1. Dirty water inside pump
    2. Leaking connections on suction side of pump
    3. No water in pump
    4. Pump worn
    5. Strainer clogged

22. Possible causes of a gasoline engine not starting include
    1. Break in ignition wiring.
    2. Distributor cap damp.
    3. Engine valves out of time/spark advance.
    4. Poor battery connection/engine will not crank.
    5. Radiator empty.

23. The keys to prolonged life of a battery are to keep the
    1. Battery fully charged.
    2. Battery operating continuously.
    3. Booster terminals connected to the battery.
    4. Electrolyte level above the cell plates.
    5. Terminals and top clean.

24. Solids are commonly classified as
    1. Inorganic and dissolved.
    2. Inorganic and suspended.
    3. Inorganic and organic.
    4. Organic and dissolved.
    5. Organic and suspended.

25. Hydrogen sulfide gas may
    1. Cause odor problems.
    2. Create a toxic atmosphere.
    3. Damage concrete in plant.
    4. Make wastes more difficult to treat.
    5. Produce an explosive and flammable condition.

Short Answer

1. Define the following items:
   a. Batch process
   b. Bulking
   c. Coagulation
   d. Filamentous bacteria
   e. RAS

2. Why are pure oxygen reactors in the activated sludge process staged?

3. How can variations or fluctuations in influent organic loadings be smoothed out before the aeration basin?

4. What safety precautions are required for handling ferric chloride in concentrated solutions?

5. Why should the backwash water for a gravity filter be of the best quality available?

6. Why are chemicals commonly used with a filtration process?

7. Define the following terms:
   a. Recalcine
   b. Slake

8. What is luxury uptake of phosphorus?

9. Why are treatment plants being designed and constructed with sophisticated instrument-control systems?

10. Why are instruments used instead of our human senses of seeing, hearing, touching, and smelling?

11. What does a thermocouple measure?

12. What does a Bourdon Tube measure?

13. What is the purpose of transmitting instruments?

14. Why are detection devices for explosive gases installed in the headworks of treatment plants?

15. How is air flow measured in the activated sludge process?

16. List the adverse characteristics of industrial wastes that could seriously impact on collection systems.

17. How would you collect a representative sample when the wastewater has oil or other floating materials on the surface?

18. What would you do if a gasoline, solvent or other type of hydrocarbon entered your treatment plant?

19. Define the following terms:
    a. Adsorption
    b. Acidity
    c. Defining
    d. Micron
    e. Ultrafiltration

20. Name three ways in which water can become biologically contaminated.

21. Heavy plugging of a screen could be caused by what factors?

22. How does pH effect the rate of corrosion?

23. Why should ventilation be provided in chemical feed facilities?

24. What is the counter-current flow principle in the activated carbon treatment process?

25. How could activated carbon cause an oxygen deficiency in a carbon column reactor vessel?

26. Define the following terms:
    a. Air gap
    b. Cavitation
    c. Electro-chemical process

27. Why should the suction hose of a portable pump have a strainer on the end?

28. What would you do if a diaphragm pump suddenly stops pumping and the engine either quits or keeps running and the pump rod slips on the shaft?

29. What is the purpose of a carburetor on a gasoline engine?

30. What might be wrong if an air conditioner runs, but fails to cool?

Problems

1. Determine the desired waste activated sludge (WAS) flow rate using the F/M control technique. The influent flow is 4.0 MGD, total aeration tank volume is 0.8 MG, COD to aeration tank is 110 mg/L, the mixed liquor suspended solids (MLSS) are 3100 mg/L and 69 percent volatile matter, the RAS suspended solids are 6,400 mg/L and the desired food to microorganism (F/M) ratio is 0.28 lbs COD/day/lb MLVSS. Current WAS flow rate is 0.35 MGD.

2. Estimate the total volume (sum of primary and secondary) of sludge produced in gallons per day from a 2 MGD activated sludge plant. Primary clarifier influent suspended solids are 300 mg/L and 120 mg/L in the effluent. Primary effluent BOD is 175 mg/L and secondary effluent BOD is 25 mg/L. The bacterial growth rate, Y, is 0.50 lbs SS per lb BOD. Primary sludge solids are 5 percent solids and secondary solids are 1.5 percent solids.

3. Jar tests indicate that a waste activated sludge flow of 35,000 GPD with a solids concentration of 1.4 percent sludge solids will require 20 pounds per day of Polymer A or 180 pounds per day of Polymer B for successful gravity thickening. Polymer A is a dry product and costs $2.20 per dry pound. Polymer B is a liquid product and costs $0.22 per liquid pound. Find the cost of using both Polymer A and B in dollars per ton of sludge.

4. Polymer is supplied at a concentration of 0.5 pounds polymer per gallon of water being treated. The polymer feed pump delivers a flow of 0.18 GPM and the flow to the pressure filters is 6,000 GPM. Calculate the concentration or dose (mg/*L*) of polymer in the water applied to the filter.

5. Determine the suspended solids and BOD loadings on a dissolved air flotation unit if the flow is 0.8 MGD and the influent suspended solids are 1,800 mg/L with a BOD of 150 mg/L. What is the percent removal of suspended solids if the effluent suspended solids are 100 mg/L?

SUGGESTED ANSWERS FOR FINAL EXAMINATION

True-False

1. True Pure oxygen systems may be used to suppy oxygen to any of the activated sludge process modes — conventional, step-feed, complete mix or contact stabilization.

2. True Cold liquid oxygen can cause skin burns.

3. True Changes in activated sludge quality cause changes in the settling characteristics of the sludge.

4. False The activated sludge process is *NOT* controlled by attempting to achieve preconceived levels of individual variables such as MLSS, MCRT and F/M ratio.

5. True Storage often must be provided in sludge treatment and disposal systems to accommodate differences between sludge disposal rates and sludge production rates.

6. False Alum *REDUCES* the alkalinity in the water being treated during the coagulation process.

7. False An instrument is a measuring device.

8. True The scales on an indicator may be straight, curved, or circular in shape.

9. True The headworks ventilation system must be kept operating both for the operator's safety and for minimizing the accumulation of concentrations of moist or otherwise corrosive and toxic gases.

10. True A good sewer-use ordinance is the proper tool to provide the necessary authority to control industrial wastes.

11. True A good sampling point is one that is easily accessible and may be located anywhere that a representative sample may be obtained.

12. True Prompt testing of samples prevents physical, chemical and/or biological changes in the sample.

13. False Measuring the flow from an industry is equally as important as obtaining good samples.

14. True Depending on their nature and concentration, certain foreign chemicals in drinking water may produce sudden illness, or may produce long-term "chronic" illness which is not diagnosed for years, but which may have severe effects.

15. True One of the most effective means of treating pulp and paper wastes is the recovery of materials.

16. False Due to the seasonality of production and characteristic nutrient deficiency in fruit and vegetable processing water, biological treatment *MAY NOT ALWAYS BE FEASIBLE*.

17. False The dissolved air flotation system is based on the principle that the solubility of gases in a solution *INCREASES* as the pressure on the solution increases.

18. True When attempting to correct a dissolved air flotation thickener process problem, the operator must not change more than one variable at a time.

19. True Screens take up less space than clarifiers and are not so much affected in performance by changes in flow rate or temperature.

20. True One operational strategy for operating screens is to place the number of screens on line needed to handle the flows and solids to be treated.

21. True The rate of rusting or corrosion increases in rainwater and increases even more in saltwater.

22. False Short-circuiting may be caused by differences in water density due to different temperatures existing at the surface and the bottom of the clarifier.

23. False The purpose of activated carbon adsorption in wastewater treatment plants is to remove *ORGANIC POLLUTANTS* from the effluent of the treatment plant.

24. False Suction lift is the *NEGATIVE* pressure on the suction side of the pump.

25. True If the priming water for a pump contains soaps or detergents, problems can develop if a high suction lift exists.

Multiple Choice

1. 1,2, 4, 5 Gravel washing produces inorganic wastes while the other four industries produce mainly organic wastes.

2. 2 Cryogenic oxygen plants are usually shut down once every year for maintenance.

3. 3, 4, 5 RAS flow rate may be adjusted by
   1. Monitoring the depth of the sludge blanket,
   2. SVI approach, and
   3. Settleability approach.

4. 1, 2, 5 When a high organic waste load reaches an activated sludge process, the DO residual will drop due to organism activity, effluent nutrients will drop due to a lack of nutrients in most industrial wastes, and effluent turbidity will increase due to a reduction in the level of treatment.

5. 1, 2, 3, 4, 5 All items listed are major factors affecting biological nitrification — DO, nitrogenous food, pH, toxic materials, and wastewater temperature.

6. 1, 2, 3 If no coagulation occurs in a chemical treatment process, inspect applied water for a significant change, actual feeder output by catching a timed sample, and feed chemical strength. Also inspect the chemical feed pump operation, chemical supply and valve positions and solution carrier water flow and valve positions.

7. 1, 2, 3, 4 Abnormal operating conditions for microscreens include high flows, high pH levels, low applied water flows and low pH levels.

8. 1, 2, 3, 4, 5 Before starting a chemical feeder, inspect or check for direction of rotation of moving parts in motors, operation of control lights on control panel, operation of safety lock-out switches, proper voltage, and size of overload protection.

9. 1, 2, 3, 4, 5 If laboratory tests indicate high turbidity and suspended solids in the effluent of a gravity filter, check for excessive head loss, determine filter aid dosages, examine backwash cycle for complete wash, inspect for damaged bed due to backwashing, and look for fluctuating flows that could cause breakthrough.

10. 3 A micrometer should be used to measure the diameter of a replacement pump shaft.

11. 4 The primary element in a control system is also called a sensor.

12. 3, 5 Sludge blanket depths may be measured by use of a hose and an aspirator or ultrasonic transmitters and receivers.

13. 1, 2, 5 Air compressor vibration sensing devices usually measure acceleration, displacement and velocity.

14. 2, 3, 4, 5 Industrial wastes discharged into a collection system should be monitored to prevent shock loads from upsetting treatment processes and to protect operators, the public and facilities from harmful substances.

15. 1, 2, 5 Flows should be measured from an industry in order to calculate the quantities of pollutants discharged, check compliance with pretreatment requirements, and prepare accurate and equitable billing calculations.

16. 3, 4, 5 The dissolved air flotation process may be used for solids recovery, wastewater treatment and water recovery.

17. 2, 3, 4, 5 Possible causes of wastewater not flowing through a microscreen include inadequate cleaning, inadequate depth of water, wastewater not flowing to screen and overload conditions, too many solids.

18. 1, 2, 3, 4, 5 Hazardous fumes, gases or conditions that might be encountered in a confined space include gasoline vapors, hydrogen sulfide, lack of oxygen, solvent fumes and toxic gases.

19. 1, 3, 4, 5 Iron compounds used as coagulants are a potential source of iron in the effluent, corrosive, difficult to dissolve in water, and potentially dangerous if they (ferric sulfate or copperas) come in contact with quicklime.

20. 1, 3, 4 Daily operational procedures for an activated carbon process include backflushing of fine-mesh screens, measuring COD removal efficiencies, and measuring effluent turbidity.

21. 1, 2, 3, 4, 5 Possible causes of a portable pump not priming include dirty water inside pump (clean water primes better), leaking connections on suction side of pump, no water in pump, pump worn and strainer clogged.

22. 1, 2, 3, 4 Possible causes of a gasoline engine not starting include a break in the ignition wiring, distributor cap damp, engine valves out of time/spark advance, and poor battery connection/engine will not crank.

23. 1, 4, 5 The keys to prolonged life of a battery are to keep the battery fully charged, electrolyte level above the cell plates, and terminals and top clean.

24.	3	Solids may be classified as either (1) inorganic and organic, or (2) dissolved and suspended.
25.	1, 2, 3, 4, 5	Hydrogen sulfide gas is very dangerous and could cause all of the problems listed.

Short Answer

1. Define the following terms:
   a. Batch process. A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.
   b. Bulking. Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.
   c. Coagulation. The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, and draining or filtering.
   d. Filamentous bacteria. Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.
   e. RAS. **R**eturn **A**ctivated **S**ludge, mg/*L*. Settled activated sludge that is collected in the secondary clarifier and returned to the aeration basin to mix with incoming raw or primary settled wastewater.

2. Pure oxygen reactors are staged to increase the efficiency of the use of oxygen.

3. Organic loadings can be smoothed out by the use of an equalizing tank and also by keeping the contents of the equalizing tank well mixed.

4. Safety precautions required for handling ferric chloride in concentrated forms should be the same as those for acids. Wear protective clothing, face shields and gloves. Flush off all splashes on clothing and skin immediately.

5. If nonfiltered water is supplied to the backwash system, clogging of the underdrain system may occur.

6. Chemicals are commonly used with a filtration process as coagulants for the solids and turbidity to aid in their removal by filtration.

7. Define the following terms:
   a. Recalcine. A lime-recovery process in which the calcium carbonate in sludge is converted to lime by heating at 1800°F (980°C).
   b. Slake. To become mixed with water so that a true chemical reaction takes place, such as in the slaking of lime.

8. Luxury uptake of phosphorus is a biological process whereby the bacteria normally found in the activated sludge treatment portion of the secondary wastewater treatment plant are withdrawn to an environment without oxygen (anaerobic) for release of phosphorus. When the bacteria are returned to an ideal environment, the first thing they take in is phosphorus. This phosphorus take-up is known as luxury uptake.

9. Plants are being designed and constructed with sophisticated instrument and control systems because of tougher discharge and monitoring requirements and also to help operators do their job.

10. Instruments are used instead of our human senses because they provide a more accurate, consistent, sensitive and permanent means of monitoring (measuring) treatment processes.

11. A thermocouple measures temperature.

12. A Bourdon Tube measures pressure.

13. The purpose of transmitting instruments is to send the variable, as measured by the measuring device (sensor), to another device for conversion to a usable number.

14. Detection devices for explosive gases are installed in the headworks of treatment plants for safety reasons if explosive gases or vapors may reach and accumulate in the headworks.

15. Air flow in the activated sludge process is usually measured by a differential pressure metering device such as an orifice plate.

16. Adverse characteristics of industrial wastes that could have serious impacts on collection systems include acid wastes, thermal wastes, solids, oil and grease, odors, toxic substances, flammable and explosive material.

17. One method of collecting a representative sample when wastewater has oil or other floating materials on the surface is to divert the entire waste stream to a large container for a short time period. The approximate quantity of floatables or oil may be determined by measuring the material that rises to the top of the container.

18. If a gasoline, solvent or other type of hydrocarbon enters the treatment plant, take the following actions:
    1. Hold gasoline or solvent on top of primary clarifiers and allow wind to disperse fumes,
    2. Inspect wet well headworks ventilation and provide extra ventilation with blowers only (no suction of vapors into fans),
    3. Divert to holding basin,
    4. Keep personnel clear of area,
    5. In pure oxygen plants, vent and purge reactors with air, and
    6. Locate source and prevent event from happening again.

19. Define the following terms:
    a. Adsorption. The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.
    b. Acidity. The capacity of water or wastewater to neutralize bases. Acidity is a measure of how much base can be added to a liquid without causing a great change in pH.
    c. Defining. A process that arranges the activated carbon particles according to size. This process is also used to remove small particles from granular contactors to prevent excessive head loss.
    d. Micron. A unit of length. One millionth of a meter or

one thousandth of a millimeter. One micron equals 0.00004 of an inch.

e. Ultrafiltration. A membrane filtration process used for the removal of organic compounds in an aqueous (watery) solution.

20. Water can become biologically contaminated by bacteria, viruses and other microorganisms excreted from the human body and other warm-blooded animals. These excretions may reach the environment through (1) sanitary wastewater, (2) storm waters washing the land of animal wastes and (3) through certain industries, most notably slaughterhouses and tanneries.

21. Heavy plugging of a screen could be caused by
    1. High solids loads, and/or
    2. A defective cleaning system.

22. The lower the pH, the greater the rate of corrosion. If the pH of a solution is allowed to drift outside of the design range, corrosion can start.

23. Ventilation should be provided in chemical feed facilities to minimize chemical exposure to personnel, controls and equipment.

24. The counter-current flow principle is the process where flow enters the bottom of the carbon column and new or regenerated carbon is added to the top of the container. This principle allows for the oldest carbon to contact the wastewater first and the newest or more virgin carbon to make contact with the effluent last. In this manner, the wastewater is polished as it flows up through the carbon column.

25. Activated carbon could cause an oxygen deficiency in a carbon column reactor vessel because activated carbon adsorbs oxygen molecules.

26. Define the following terms:
    a. Air Gap. An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the drinking water.
    b. Cavitation. The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.
    c. Electro-chemical Process. A process that causes the deposition or formation of a seal or coating of a chemical element or compound by the use of electricity.

27. The suction hose has a strainer on the end to prevent pulling rocks and debris into the pump to avoid damaging the pump or plugging the hoses or pipes.

28. If a diaphragm pump suddenly stops pumping, remove discharge valve and clean out pump cavity.

29. The purpose of a carburetor on a gasoline engine is to produce a mixture of fuel and air on which the engine will operate.

30. If an air conditioner runs but fails to cool, some of the refrigerant charge may have been lost.

Problems

1.

Known		**Unknown**
Infl. Flow, MGD	= 4.0 MGD	WAS Flow,MGD
Tank Vol., MG	= 0.8 MG	
COD, mg/L	= 110 mg/L	
MLSS, mg/L	= 3,100 mg/L	
MLSS VM, %	= 69%	
RAS SS, mg/L	= 6,400 mg/L	
Desired F/M $\frac{\text{lbs COD/day}}{\text{lb MLVSS}}$	$= 0.28\ \frac{\text{lbs COD/day}}{\text{lb MLVSS}}$	
Current WAS, MGD	= 0.35 MGD	

a. Determine COD applied in pounds per day.

$$\begin{aligned}\text{COD, lbs/day} &= \text{Flow, MGD} \times \text{COD, mg/L} \times 8.34\ \text{lbs/gal}\\ &= 4\ \text{MGD} \times 110\ \text{mg/L} \times 8.34\ \text{lbs/gal}\\ &= 3{,}670\ \text{lbs/day}\end{aligned}$$

b. Determine the desired pounds of MLVSS.

$$\begin{aligned}\text{Desired MLVSS, lbs} &= \frac{\text{COD applied, lbs/day}}{\text{F/M, lbs COD/day/lb MLVSS}}\\ &= \frac{3{,}760\ \text{lbs COD/day}}{0.28\ \text{lbs COD/day/lb MLVSS}}\\ &= 13{,}107\ \text{lbs}\\ &\quad \text{Use } 13{,}100\ \text{lbs}^{*}\end{aligned}$$

---

* From a practical standpoint, you can't measure MLSS or MLVSS any closer than to the nearest 100 pounds.

c. Determine the desired pounds MLSS.

$$\begin{aligned}\text{Desired MLSS, lbs} &= \frac{\text{Desired MLVSS, lbs}}{\text{MLSS VM portion}}\\ &= \frac{13{,}107\ \text{lbs}}{0.69}\\ &= 18{,}996\ \text{lbs}\\ &\quad \text{Use } 19{,}000\ \text{lbs}\end{aligned}$$

d. Determine actual MLSS pounds under aeration.

$$\begin{aligned}\text{Actual MLSS, lbs} &= \text{Tank Vol, MG} \times \text{MLSS, mg/L} \times 8.34\ \text{lbs/gal}\\ &= 0.8\ \text{MG} \times 3{,}100\ \text{mg/L} \times 8.34\ \text{lbs/gal}\\ &= 20{,}683\ \text{lbs}\\ &\quad \text{Use } 20{,}700\ \text{lbs}\end{aligned}$$

e. Calculate the additional WAS, MGD, to maintain the desired food to microorganism (F/M) ratio.

$$\begin{aligned}\text{Additional WAS Flow, MGD} &= \frac{\text{Actual MLSS, lbs} - \text{Desired MLSS, lbs}}{\text{RAS SS, mg/L} \times 8.34\ \text{lbs/gal}}\\ &= \frac{20{,}700\ \text{lbs} - 19{,}000\ \text{lbs}}{6{,}400\ \text{mg/L} \times 8.34\ \text{lbs/gal}}\\ &= 0.032\ \text{MGD} \times 694\ \text{GPM/MGD}\\ &= 22\ \text{GPM}\end{aligned}$$

f. Calculate the total WAS flow in MGD and GPM.

$$\begin{aligned}\text{Total WAS Flow, MGD} &= \text{Current WAS Flow, MGD} + \text{Additional WAS Flow, MGD}\\ &= 0.35\ \text{MGD} + 0.032\ \text{MGD}\\ &= 0.382\ \text{MGD} \times 694\ \text{GPM/MGD}\\ &= 265\ \text{GPM}\end{aligned}$$

2.

Known		Unknown
Flow, MGD	= 2 MGD	Volume of Sludge, gal/day
Prim Effl SS, mg/L	= 120 mg/L	
Prim Infl SS, mg/L	= 300 mg/L	
Prim Effl BOD, mg/L	= 175 mg/L	
Sec Effl BOD, mg/L	= 25 mg/L	
Y, lbs SS/lb BOD	= 0.5 lbs SS/lb BOD	
Prim Sludge Solids, %	= 5%	
Sec Sludge Solids, %	= 1.5%	

a. Calculate the amount of dry primary sludge produced in pounds per day.

$$\begin{aligned}\text{Primary Sludge, lbs/day} &= \text{Flow, MGD (In SS, mg/L} - \text{Ef SS, mg/L) 8.34 lbs/gal}\\ &= \text{2 MGD (300 mg/L} = \text{120 mg/L) 8.34 lbs/gal}\\ &= \text{3000 lbs/day (dry solids)}\end{aligned}$$

b. Calculate the amount of BOD removed by the secondary system in lbs BOD per day.

$$\begin{aligned}\text{BOD Removed, lbs/day} &= \text{Flow, MGD (BOD In, mg/L} - \text{BOD Out, mg/L) 8.34 lbs/gal}\\ &= \text{2 MGD (175 mg/L} - \text{25 mg/L) 8.34 lbs/gal}\\ &= \text{2500 lbs BOD/day}\end{aligned}$$

c. Determine the secondary sludge produced in terms of dry sludge solids per day.

$$\begin{aligned}\text{Sludge Produced lbs dry solids/day} &= \text{BOD Removed, lbs BOD/day} \times \text{Y, } \frac{\text{lbs Sl Sol Prod/day}}{\text{lbs BOD Removed/day}}\\ &= \text{2500 lbs BOD/day} \times \frac{\text{0.5 lbs Sl Sol/day}}{\text{1 lb BOD/day}}\\ &= \text{1250 lbs dry sludge solids/day}\end{aligned}$$

d. Estimate the total volume of sludge produced in gallons per day.

$$\begin{aligned}\text{Sludge Volume, gal/day} &= \text{Primary Sludge Volume, gal/day} + \text{Secondary Sludge Volume, gal/day}\\ &= \frac{\text{Prim Sludge, lbs dry solids/day}}{\text{Prim Sludge Solids, \%/100\%} \times \text{8.34 lbs/gal}}\\ &\quad + \frac{\text{Sec Sludge, lbs/dry solids/day}}{\text{Sec Sludge Solids, \%/100\%} \times \text{8.34 lbs/gal}}\\ &= \frac{\text{3000 lbs/day}}{\text{5\%/100\%} \times \text{8.34 lbs/gal}} + \frac{\text{1250 lbs/day}}{\text{1.5\%/100\%} \times \text{8.34 lbs/gal}}\\ &= \text{7200 gal/day + 10,000 gal/day}\\ &= \text{17,200 gal/day}\end{aligned}$$

3.

Known		Unknown
Jar Tests on Waste Activated Sludge		Costs of Polymers A and B, $/ton of sludge
Flow, GPD	= 35,000 GPD	
Sl Sol, %	= 1.4%	
Polymer A, lbs/day	= 20 lbs/day	
Polymer B, lbs/day	= 180 lbs/day	
Polymer A, $/lb	= $2.20/dry lb	
Polymer B, $/lb	= $0.22/liquid lb	

a. Determine the polymer dosage in pounds of polymer per ton of sludge for both Polymer A and B.

1. Calculate the tons of dry sludge solids per day treated by the polymers.

$$\begin{aligned}\text{Sludge, tons/day} &= \frac{\text{Flow, GPD} \times \text{8.34 lbs/gal} \times \text{Sl Sol, \%/100\%}}{\text{2000 lbs/ton}}\\ &= \frac{\text{35,000 gal/day} \times \text{8.34 lbs/gal} \times \text{1.5\%/100\%}}{\text{2000 lbs/ton}}\\ &= \text{2.19 tons/day}\end{aligned}$$

2. Calculate the dosage of Polymer A in dry pounds of polymer per ton of sludge solids.

$$\begin{aligned}\text{Polymer A Dose, } \frac{\text{lbs polymer}}{\text{ton sludge}} &= \frac{\text{Amount of Polymer A, lbs/day}}{\text{Sludge, tons/day}}\\ &= \frac{\text{20 lbs Polymer A/day}}{\text{2.19 tons/day}}\\ &= \text{9.1 lbs dry Polymer A/ton sludge}\end{aligned}$$

3. Calculate the dosage for Polymer B in liquid pounds of polymer per ton of sludge solids.

$$\begin{aligned}\text{Polymer B Dose, } \frac{\text{lbs polymer}}{\text{ton sludge}} &= \frac{\text{Amount of Polymer B, lbs/day}}{\text{Sludge, tons/day}}\\ &= \frac{\text{180 lbs Polymer B/day}}{\text{2.19 tons/day}}\\ &= \text{82.2 lbs liquid Polymer B/ton sludge}\end{aligned}$$

b. Calculate cost for Polymer A in dollars of polymer per ton of sludge solids treated.

$$\begin{aligned}\text{Cost, \$/ton} &= \text{Dose, } \frac{\text{lbs polymer}}{\text{ton sludge}} \times \text{Polymer Cost, \$/lb}\\ &= 9.1\ \frac{\text{lbs polymer}}{\text{ton sludge}} \times \text{\$2.20/lb polymer}\\ &= \text{\$20.02/ton of sludge}\end{aligned}$$

c. Calculate the cost for Polymer B in dollars of polymer per ton of sludge solids treated.

$$\begin{aligned}\text{Cost, \$/ton} &= \text{Dose, } \frac{\text{lbs polymer}}{\text{ton sludge}} \times \text{Polymer Cost, \$/lb}\\ &= 82.2\ \frac{\text{lbs polymer}}{\text{ton sludge}} \times \text{\$0.22/lb polymer}\\ &= \text{\$18.08/ton of sludge}\end{aligned}$$

4.

Known		Unknown
Polymer Conc., lb/gal	= 0.5 lbs/gal	Polymer Dose, mg/*L*
Polymer Pump, GPM	= 0.18 GPM	
Flow to Filter, GPM	= 6,000 GPM	

Calculate the polymer dose in mg/*L*.

$$\begin{aligned}\text{Dose, mg/}L &= \frac{\text{Flow, gal/min} \times \text{Conc., lbs polymer/gal}}{\text{Flow, gal/min} \times \text{8.34 lbs/gal}}\\ &= \frac{\text{0.18 gal/min} \times \text{0.5 lbs/gal}}{\text{6,000 gal/min} \times \text{8.34 lbs/gal}}\\ &= \frac{\text{0.09 lbs polymer}}{\text{50,040 lbs water}} \times \frac{1{,}000{,}000}{\text{1 M}}\\ &= \text{1.8 mg/}L\end{aligned}$$

5. **Known**

Flow, MGD = 0.8 MGD
Infl SS, mg/*L* = 1,800 mg/*L*
Effl SS, mg/*L* = 100 mg/*L*
Infl BOD, mg/*L* = 150 mg/*L*

Unknown

1. SS Loading, lbs/day
2. BOD Loading, lbs/day
3. SS Removal, %

a. Calculate the influent suspended solids loading in pounds per day.

$$\begin{aligned}\text{SS Loading, lbs/day} &= \text{Flow, MGD} \times \text{Infl SS, mg}/L \times 8.34 \text{ lbs/gal}\\ &= 0.8 \text{ MGD} \times 1800 \text{ mg}/L \times 8.34 \text{ lbs/gal}\\ &= 12{,}000 \text{ lbs suspended solids/day}\end{aligned}$$

b. Calculate the influent BOD loading in pounds BOD per day.

$$\begin{aligned}\text{BOD Loading, lbs/day} &= \text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34 \text{ lbs/gal}\\ &= 0.8 \text{ MGD} = \times\ 150 \text{ mg}/L \times 8.34 \text{ lbs/gal}\\ &= 1{,}000 \text{ lbs BOD/day}\end{aligned}$$

c. Determine the percent suspended solids removal.

$$\begin{aligned}\text{SS Removal, \%} &= \frac{(\text{Infl SS, mg}/L - \text{Effl SS, mg}/L)}{\text{Infl SS, mg}/L}\\ &= \frac{(1800 \text{ mg}/L - 100 \text{ mg}/L)}{1800 \text{ mg}/L} 100\%\\ &= 94.4\%\end{aligned}$$

GLOSSARY

A Summary of the Words Defined

in

INDUSTRIAL WASTE TREATMENT

Project Pronunciation Key

by Warren L. Prentice

The Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This key is designed solely to aid operators in this program.

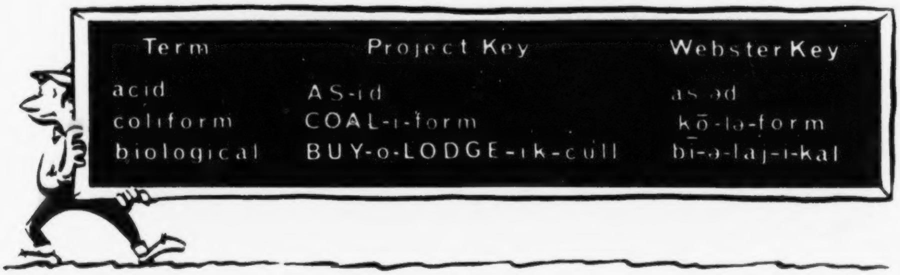
You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation key. Each key will be different from each other and from this key. Examples of the difference between the key used in this program and the Webster's *NEW WORLD DICTIONARY* "Key"[1] are shown below:

In using this key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Project Key.

	SYLLABLE				
WORD	1st	2nd	3rd	4th	5th
acid	AS	id			
coagulant	co	AGG	you	lent	
biological	BUY	o	LODGE	ik	cull

The first word, *ACID*, has its first syllable accented. The second word, *COAGULANT*, has its second syllable accented. The third word, *BIOLOGICAL*, has its first and third syllables accented.

We hope you will find the key useful in unlocking the pronunciation of any new word.



Term	Project Key	Webster Key
acid	AS-id	as-əd
coliform	COAL-i-form	kō-lə-form
biological	BUY-o-LODGE-ik-cull	bī-ə-laj-i-kal

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[1] *The Webster's* NEW WORLD DICTIONARY, *College Edition, 1968, was chosen rather than an unabridged dictionary because of its availability to the operator.*

GLOSSARY

ABS ABS

Alkyl **B**enzene **S**ulfonate. A type of surfactant, or surface active agent, present in synthetic detergents in the United States before 1965. ABS was especially troublesome because it caused foaming and resisted breakdown by biological treatment processes. ABS has been replaced in detergents by **l**inear **a**lkyl **s**ulfonate (LAS) which is biodegradable.

ABSORPTION (ab-SORP-shun) ABSORPTION

Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACID ACID

(1) A substance that tends to lose a proton. (2) A substance that dissolves in water with the formation of hydrogen ions. (3) A substance containing hydrogen which may be replaced by metals to form salts.

ACIDITY ACIDITY

The capacity of water or wastewater to neutralize bases. Acidity is expressed in milligrams per liter of equivalent calcium carbonate. Acidity is not the same as pH because water does not have to be strongly acidic (low pH) to have a high acidity. Acidity is a measure of how much base can be added to a liquid without causing a great change in pH.

ACTIVATED SLUDGE (ACK-ta-VATE-ed sluj) ACTIVATED SLUDGE

Sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, fungi, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.

ACTIVATED SLUDGE PROCESS (ACK-ta-VATE-ed sluj) ACTIVATED SLUDGE PROCESS

A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.

ADSORPTION (add-SORP-shun) ADSORPTION

The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.

ADVANCED WASTE TREATMENT ADVANCED WASTE TREATMENT

Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration. Also called TERTIARY TREATMENT.

AERATION (air-A-shun) AERATION

The process of adding air. In wastewater treatment, air is added to freshen wastewater and to keep solids in suspension. With mixtures of wastewater and activated sludge, adding air provides mixing and oxygen for the microorganisms treating the wastewater.

AERATION LIQUOR (air-A-shun) AERATION LIQUOR

Mixed liquor. The contents of the aeration tank including living organisms and material carried into the tank by either untreated wastewater or primary effluent.

AERATION TANK (air-A-shun) AERATION TANK

The tank where raw or settled wastewater is mixed with return sludge and aerated. The same as aeration bay, aerator, or reactor.

AEROBES AEROBES

Bacteria that must have molecular (dissolved) oxygen (DO) to survive. Aerobes are aerobic bacteria.

AEROBIC (AIR-O-bick) AEROBIC

A condition in which "free" or dissolved oxygen is present in the aquatic environment.

AEROBIC BACTERIA (AIR-O-bick back-TEAR-e-ah) AEROBIC BACTERIA

Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobic bacteria.

AEROBIC DECOMPOSITION (AIR-O-bick) AEROBIC DECOMPOSITION

The decay or breaking down of organic material in the presence of "free" or dissolved oxygen.

AEROBIC DIGESTION (AIR-O-bick) AEROBIC DIGESTION

The breakdown of wastes by microorganisms in the presence of dissolved oxygen. Waste sludge is placed in a large aerated tank where aerobic microorganisms decompose the organic matter in the sludge. This is an extension of the activated sludge process.

AEROBIC PROCESS (AIR-O-bick) AEROBIC PROCESS

A waste treatment process conducted under aerobic (in the presence of "free" or dissolved oxygen) conditions.

AGE TANK AGE TANK

A tank used to store a known concentration of chemical solution for feed to a chemical feeder. Also called a "day tank."

AGGLOMERATION (a-GLOM-er-A-shun) AGGLOMERATION

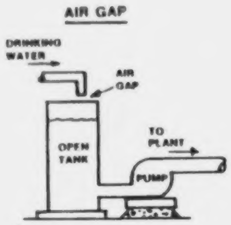
The growing or coming together of small scattered particles into larger flocs or particles which settle rapidly. Also see FLOC.

AIR BINDING AIR BINDING

The clogging of a filter, pipe or pump due to the presence of air released from water.

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the drinking water.



AIR LIFT AIR LIFT

A special type of pump. This device consists of a vertical riser pipe submerged in the wastewater or sludge to be pumped. Compressed air is injected into a tail piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An air-lift pump works similar to the center stand in a percolator coffee pot.

AIR PADDING AIR PADDING

Pumping dry air into a container to assist with the withdrawal of a liquid or to force a liquid gas such as chlorine or sulfur dioxide out of a container.

ALGAE (AL-gee) ALGAE

Microscopic plants which contain chlorophyll and float or are suspended and live in water. They also may be attached to structures, rocks, or other similar substances.

ALIQUOT (AL-li-kwot) ALIQUOT

Portion of a sample.

ALKALI ALKALI

Any of certain soluble salts, principally of sodium, potassium, magnesium, and calcium, that have the property of combining with acids to form neutral salts and may be used in chemical processes such as water or wastewater treatment.

ALKALINITY (AL-ka-LIN-ity) ALKALINITY

The capacity of water or wastewater to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.

AMBIENT TEMPERATURE (AM-bee-ent) AMBIENT TEMPERATURE

Temperature of the surroundings.

AMPEROMETRIC (am-PURR-o-MET-rick) AMPEROMETRIC

A method of measurement that records electric current flowing or generated, rather than recording voltage. Amperometric titration is a means of measuring concentrations of certain substances in water.

ANAEROBES ANAEROBES

Bacteria that do not need molecular (dissolved) oxygen (DO) to survive.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" or dissolved oxygen is *NOT* present in the aquatic environment.

ANAEROBIC BACTERIA (AN-air-O-bick back-TEAR-e-ah) ANAEROBIC BACTERIA

Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4).

ANAEROBIC DECOMPOSITION (AN-air-O-bick) ANAEROBIC DECOMPOSITION

The decay or breaking down of organic material in an environment containing no "free" or dissolved oxygen.

ANAEROBIC DIGESTION (AN-air-O-bick) ANAEROBIC DIGESTION

Wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen. At least two general groups of bacteria act in balance: (1) *SAPROPHYTIC* bacteria break down complex solids to volatile acids, and (2) *METHANE FERMENTERS* break down the acids to methane, carbon dioxide, and water.

ANHYDROUS (an-HI-drous) ANHYDROUS

Very dry. No water or dampness is present.

ANION ANION

A negatively charged ion in an electrolyte solution, attracted to the anode under the influence of electric potential.

ASEPTIC (a-SEP-tick) ASEPTIC

Free from the living germs of disease, fermentation or putrefaction. Sterile.

ASPIRATE (ASS-per-RATE) ASPIRATE

Use of a hydraulic device (aspirator or eductor) to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump; sometimes used instead of a sump pump.

BOD (BEE-OH-DEE) BOD

Biochemical Oxygen Demand. The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BTU (BEE-TEA-YOU) BTU

British Thermal Unit. The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

BACTERIA (back-TEAR-e-ah) BACTERIA

Bacteria are living organisms, microscopic in size, which consist of a single cell. Most bacteria utilize organic matter for their food and produce waste products as the result of their life processes.

BACTERIAL CULTURE (back-TEAR-e-al) BACTERIAL CULTURE

In the case of activated sludge, the bacterial culture refers to the group of bacteria classed as *AEROBES*, and facultative organisms, which covers a wide range of organisms. Most treatment processes in the United States grow facultative organisms which utilize the carbonaceous (carbon compounds) BOD. Facultative organisms can live when oxygen resources are low. When "nitrification" is required, the nitrifying organisms are *OBLIGATE AEROBES* (require oxygen) and must have at least 0.5 mg/L of dissolved oxygen throughout the whole system to function properly.

BAFFLE BAFFLE

A flat board or plate, deflector, guide or similar device constructed or placed in flowing water, wastewater, or slurry systems to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate liquids.

BASE BASE

A compound which dissociates (separates) in aqueous solution to yield hydroxyl ions.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

BENCH SCALE ANALYSIS BENCH SCALE ANALYSIS

A method of studying different ways of treating wastewater and solids on a small scale in a laboratory.

BENZENE BENZENE

An aromatic hydrocarbon (C_6H_6) which is a colorless, volatile, flammable liquid. Benzene is obtained chiefly from coal tar and is used as a solvent for resins and fats in the manufacture of dyes.

BIOASSAY (BUY-o-ass-SAY) BIOASSAY

(1) A way of showing or measuring the effect of biological treatment on a particular substance or waste, or (2) a method of determining toxic effects of industrial wastes or other wastes by using live organisms such as fish for test organisms.

BIOCHEMICAL OXYGEN DEMAND (BOD) BIOCHEMICAL OXYGEN DEMAND (BOD)

The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BIOCHEMICAL OXYGEN DEMAND (BOD) TEST BIOCHEMICAL OXYGEN DEMAND (BOD) TEST

A procedure that measures the rate of oxygen use under controlled conditions of time and temperature. Standard test conditions include dark incubation at 20°C for a specified time (usually five days).

BIODEGRADABLE (BUY-o-dee-GRADE-able) BIODEGRADABLE

Organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odors.

BIODEGRADATION (BUY-o-de-grah-DAY-shun) BIODEGRADATION

The breakdown of organic matter by bacteria to more stable forms which will not create a nuisance or give off foul odors.

BIOFLOCCULATION (BUY-o-flock-u-LAY-shun) BIOFLOCCULATION

The clumping together of fine, dispersed organic particles by the action of certain bacteria and algae. This results in faster and more complete settling of the organic solids in wastewater.

BIOMASS (BUY-o-MASS) BIOMASS

A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris. This mass may be formed for, or function as, the protection against predators and storage of food supplies. Also see ZOOGLEAL MASS.

BLANK BLANK

A bottle containing only dilution water or distilled water, but the sample being tested is not added. Tests are frequently run on a *SAMPLE* and a *BLANK* and the differences compared.

BLINDING BLINDING

The clogging of the filtering medium of a microscreen or a vacuum filter when the holes or spaces in the media become sealed off due to a buildup of grease or the material being filtered.

BOUND WATER BOUND WATER

Water contained within the cell mass of sludges or strongly held on the surface of colloidal particles.

BREAKOUT OF CHLORINE BREAKOUT OF CHLORINE

A point at which chlorine leaves solution as a gas because the chlorine feed rate is too high. The solution is saturated and cannot dissolve any more chlorine.

BREAKPOINT CHLORINATION BREAKPOINT CHLORINATION

Addition of chlorine to water or wastewater until the chlorine demand has been satisfied and further additions of chlorine result in a residual that is directly proportional to the amount added beyond the breakpoint.

BUFFER BUFFER

A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BUFFER ACTION BUFFER ACTION

The action of certain ions in solution in opposing a change in hydrogen-ion concentration.

BUFFER CAPACITY BUFFER CAPACITY

A measure of the capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water or wastewater for offering a resistance to changes in pH.

BUFFER SOLUTION BUFFER SOLUTION

A solution containing two or more substances which, in combination, resist any marked change in pH following addition of moderate amounts of either strong acid or base.

BULKING (BULK-ing) BULKING

Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.

CALORIE (KAL-o-ree) CALORIE

The amount of heat required to raise the temperature of one gram of water one degree Celsius.

CARBONACEOUS STAGE (car-bun-NAY-shus) CARBONACEOUS

A stage of decomposition that occurs in biological treatment processes when aerobic bacteria, using dissolved oxygen, change carbon compounds to carbon dioxide. Sometimes referred to as "first-stage BOD" because the microorganisms attack organic or carbon compounds first and nitrogen compounds later. Also see NITRIFICATION STAGE.

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.

CATION EXCHANGE CAPACITY CATION EXCHANGE CAPACITY

The ability of a soil or other solid to exchange cations (positive ions such as calcium, Ca^{+2}) with a liquid.

CAVITATION (CAV-i-TAY-shun) CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.

CENTRATE CENTRATE

The water leaving a centrifuge after most of the solids have been removed.

CENTRIFUGE CENTRIFUGE

A mechanical device that uses centrifugal or rotational forces to separate solids from liquids.

CHEMICAL EQUIVALENT CHEMICAL EQUIVALENT

The weight in grams of a substance that combines with or displaces one gram of hydrogen. Chemical equivalents usually are found by dividing the formula weight by its valence.

CHEMICAL OXYGEN DEMAND or COD CHEMICAL OXYGEN DEMAND or COD

A measure of the oxygen-consuming capacity of inorganic and organic matter present in wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/L during a specific test. Results are not necessarily related to the biochemical oxygen demand because the chemical oxidant may react with substances that bacteria do not stabilize.

CHEMICAL PRECIPITATION CHEMICAL PRECIPITATION

(1) Precipitation induced by addition of chemicals. (2) The process of softening water by the addition of lime or lime and soda ash as the precipitants.

CHLORAMINES (KLOR-a-means) CHLORAMINES

Chloramines are compounds formed by the reaction of chlorine with ammonia.

CHLORINATION (KLOR-i-NAY-shun) CHLORINATION

The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

CHLORINE DEMAND CHLORINE DEMAND

Chlorine demand is the difference between the amount of chlorine added to wastewater and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of the impurities in the water.

Chlorine Demand, mg/*L* = Chlorine Applied, mg/*L* − Chlorine Residual, mg/*L*

CHLORINE REQUIREMENT CHLORINE REQUIREMENT

The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or destroying some chemical in the water. In each case a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CHLORORGANIC (chloro-or-GAN-nick) CHLORORGANIC

Chlororganic compounds are organic compounds combined with chlorine. These compounds generally originate from, or are associated with, living or dead organic materials.

CILIATES (SILLY-ates) CILIATES

A class of protozoans distinguished by short hairs on all or part of their bodies.

CLARIFICATION (KLAIR-i-fi-KAY-shun) CLARIFICATION

Any process or combination of processes the main purpose of which is to reduce the concentration of suspended matter in a liquid.

CLARIFIER (KLAIR-i-fire) CLARIFIER

Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time, during which the heavier solids settle to the bottom and the lighter material will float to the water surface.

COAGULANT AID COAGULANT AID

Any chemical or substance used to assist or modify coagulation.

COAGULANTS (co-AGG-you-lents) COAGULANTS

Chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COAGULATION (co-AGG-you-LAY-shun) COAGULATION

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COLIFORM (COAL-i-form) COLIFORM

One type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes other environmental sources.

COLLOIDS (KOL-loids) COLLOIDS

Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

COLORIMETRIC MEASUREMENT COLORIMETRIC MEASUREMENT

A means of measuring unknown concentrations of water quality indicators in a sample by measuring the sample's color intensity. The color of the sample after the addition of specific chemicals (reagents) is compared with colors of known concentrations.

COMBINED AVAILABLE CHLORINE COMBINED AVAILABLE CHLORINE

The concentration of chlorine which is combined with ammonia (NH_3) as chloramine or as other chloro derivatives, yet is still available to oxidize organic matter.

COMBINED AVAILABLE RESIDUAL CHLORINE COMBINED AVAILABLE RESIDUAL CHLORINE

That portion of the total residual chlorine which remains in water or wastewater at the end of a specified contact period and reacts chemically and biologically as chloramines or organic chloramines.

COMBINED RESIDUAL CHLORINATION COMBINED RESIDUAL CHLORINATION

The application of chlorine to water or wastewater to produce a combined chlorine residual. The residual may consist of chlorine compounds formed by the reaction of chlorine with natural or added ammonia (NH_3) or with certain organic nitrogen compounds.

COMBINED SEWER COMBINED SEWER

A sewer designed to carry both sanitary wastewaters and storm- or surface-water runoff.

COMMINUTION (com-mi-NEW-shun) COMMINUTION

Shredding. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment. *COMMINUTION* and *SHREDDING* usually mean the same thing.

COMMINUTOR (com-mi-NEW-ter) COMMINUTOR

A device used to reduce the size of the solid chunks in wastewater by shredding (comminuting). The shredding action is like many scissors cutting or chopping to shreds all the large influent solids material.

COMPOSITE (PROPORTIONAL) SAMPLE (com-POZ-it) COMPOSITE (PROPORTIONAL) SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

COMPOUND COMPOUND

A pure substance composed of two or more elements whose composition is constant. For example, table salt (sodium chloride - Na Cl) is a compound.

CONING (CONE-ing) CONING

Development of a cone-shaped flow of liquid, like a whirlpool, through sludge. This can occur in a sludge hopper during sludge withdrawal when the sludge becomes too thick. Part of the sludge remains in place while liquid rather than sludge flows out of the hopper. Also called "coring."

CONTACT STABILIZATION CONTACT STABILIZATION

Contact stabilization is a modification of the conventional activated sludge process. In contact stabilization, two aeration tanks are used. One tank is for separate re-aeration of the return sludge for at least four hours before it is permitted to flow into the other aeration tank to be mixed with the primary effluent requiring treatment.

CONTINUOUS PROCESS CONTINUOUS PROCESS

A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.

CONVENTIONAL TREATMENT CONVENTIONAL TREATMENT

The pretreatment, sedimentation, flotation, trickling filter, activated sludge and chlorination wastewater treatment processes.

CROSS CONNECTION CROSS CONNECTION

A connection between drinking (potable) water and an unsafe water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

CRYOGENIC (cry-o-JEN-nick) CRYOGENIC

Low temperature.

DO (DEE-OH) DO

Abbreviation of Dissolved Oxygen. DO is the atmospheric oxygen dissolved in water or wastewater.

DATEOMETER (day-TOM-uh-ter) DATEOMETER

A small calendar disc attached to motors and equipment to indicate the year in which the last maintenance service was performed.

DAY TANK DAY TANK

A tank used to store a known concentration of chemical solution for feed to a chemical feeder. Also called an "age tank."

DECHLORINATION (dee-KLOR-i-NAY-shun) DECHLORINATION

The removal of chlorine from the effluent of a treatment plant.

DECIBEL DECIBEL

A unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average pain level.

DECOMPOSITION, DECAY DECOMPOSITION, DECAY

Processes that convert unstable materials into more stable forms by chemical or biological action. Waste treatment encourages decay in a controlled situation so that material may be disposed of in a stable form. When organic matter decays under anaerobic conditions (putrefaction), undesirable odors are produced. The aerobic processes in common use for wastewater treatment produce much less objectional odors.

DEFINING DEFINING

A process that arranges the activated carbon particles according to size. This process is also used to remove small particles from granular contactors to prevent excessive head loss.

DEGRADATION (de-grah-DAY-shun) DEGRADATION

The conversion of a substance to simpler compounds. For example, the degradation of organic matter to carbon dioxide and water.

DENITRIFICATION DENITRIFICATION

A condition that occurs when nitrite or nitrate ions are reduced to nitrogen gas and bubbles are formed as a result of this process. The bubbles attach to the biological flocs and float the flocs to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers or gravity thickeners.

DENSITY (DEN-sit-tee) DENSITY

A measure of how heavy a substance (solid, liquid or gas) is for its size. Density is expressed in terms of weight per unit volume, that is, grams per cubic centimeter or pounds per cubic foot. The density of water (at 4°C or 39°F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot.

DESICCATOR (DESS-i-KAY-tor) DESICCATOR

A closed container into which heated weighing or drying dishes are placed to cool in a dry environment. The dishes may be empty or they may contain a sample. Desiccators contain a substance, such as anhydrous calcium chloride, which absorbs moisture and keeps the relative humidity near zero so that the dish or sample will not gain weight from absorbed moisture.

DETENTION TIME DETENTION TIME

The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DETRITUS (dee-TRI-tus) DETRITUS

The heavy, coarse mixture of grit and organic material carried by wastewater.

DEW POINT DEW POINT

The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air.

DEWATER DEWATER

To remove or separate a portion of the water present in a sludge or slurry.

DEWATERABLE DEWATERABLE

This is a property of a sludge related to the ability to separate the liquid portion from the solid, with or without chemical conditioning. A material is considered dewaterable if water will readily drain from it.

DIAPHRAGM PUMP DIAPHRAGM PUMP

The pump in which a flexible diaphragm, generally of rubber or equally flexible material, is the operating part. It is fastened at the edges in a vertical cylinder. When the diaphragm is raised suction is exerted, and when it is depressed, the liquid is forced through a discharge valve.

DIATOM DIATOM

A group of microscopic, unicellular, marine or fresh-water algae having siliceous (consisting of silica) cell walls.

DIATOMACEOUS EARTH DIATOMACEOUS EARTH

A fine, siliceous earth consisting mainly of the skeletal remains of diatoms.

DIFFUSED-AIR AERATION DIFFUSED-AIR AERATION

A diffused air activated sludge plant takes air, compresses it, and then discharges the air below the water surface of the aerator through some type of air diffusion device.

DIFFUSER DIFFUSER

A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DIGESTER (die-JEST-er) DIGESTER

A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic (more common) or aerobic conditions.

DISCHARGE HEAD DISCHARGE HEAD

The pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the discharge side of a pump. The pressure can be measured from the center line of the pump to the hydraulic grade line of the water in the discharge pipe.

DISINFECTION (dis-in-FECT-shun) DISINFECTION

The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being most frequently used in water and wastewater treatment plants. Compare with STERILIZATION.

DISSOLVED OXYGEN DISSOLVED OXYGEN

Molecular oxygen dissolved in water or wastewater, usually abbreviated DO.

DISTILLATE (DIS-tuh-late) DISTILLATE

In the distillation of a sample, a portion is evaporated; the part that is condensed afterwards is the distillate.

DISTRIBUTOR DISTRIBUTOR

The rotating mechanism that distributes the wastewater evenly over the surface of a trickling filter or other process unit. Also see FIXED SPRAY NOZZLE.

DOCTOR BLADE DOCTOR BLADE

A blade used to remove any excess solids that may cling to the outside of a rotating screen.

DRAIN TILE SYSTEMS DRAIN TILE SYSTEMS

A system of tile pipes buried under the crops that collect percolated waters and keep the groundwater table below the ground surface to prevent ponding.

DRAINAGE WELLS DRAINAGE WELLS

Wells that can be pumped to lower the groundwater table and prevent ponding.

DROOP DROOP

The difference between the actual value and the desired value (or set point) characteristics of proportional controllers that do not incorporate reset action. Also called OFFSET.

DYNAMIC HEAD DYNAMIC HEAD

When a pump is operating, the vertical distance (in feet or meters) from a point to the energy grade lines. Also see TOTAL DYNAMIC HEAD and STATIC HEAD.

EDUCTOR (e-DUCK-tor) EDUCTOR

A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump; sometimes used instead of a suction pump.

EFFLORESCENCE (EF-low-RESS-ense) EFFLORESCENCE

The powder or crust formed on a substance when moisture is given off upon exposure to the atmosphere.

EFFLUENT (EF-lu-ent) EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

ELECTRO-CHEMICAL CORROSION ELECTRO-CHEMICAL CORROSION

The decomposition of a material by: (1) stray current electrolysis, (2) galvanic corrosion caused by dissimilar metals, and (3) galvanic corrosion caused by differential electrolysis.

ELECTRO-CHEMICAL PROCESS ELECTRO-CHEMICAL PROCESS

A process that causes the deposition or formation of a seal or coating of a chemical element or compound by the use of electricity.

ELECTRO-MAGNETIC FORCES ELECTRO-MAGNETIC FORCES

Forces resulting from electrical charges that either attract or repel particles. Particles with opposite charges are attracted to each other. For example, a particle with positive charges is attracted to a particle with negative charges. Particles with similar charges repel each other. A particle with positive charges is repelled by a particle with positive charges and a particle with negative charges is repelled by another particle with negative charges.

ELECTROLYSIS (ELECT-TROLLEY-sis) ELECTROLYSIS

The decomposition of material by an electric current.

ELECTROLYTE (ELECT-tro-LIGHT) ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

ELECTROLYTIC PROCESS (ELECT-tro-LIT-ick) ELECTROLYTIC PROCESS

A process that causes the decomposition of a chemical compound by the use of electricity.

ELECTRON ELECTRON

An extremely small (microscopic), negatively charged particle. An electron is much too small to be seen with a microscope.

ELEMENT ELEMENT

A substance which cannot be separated into substances of other kinds by ordinary chemical means. For example, sodium (Na) is an element.

ELUTRIATION (e-LOO-tree-A-shun) ELUTRIATION

The washing of digested sludge in plant effluent. The objective is to remove (wash out) fine particulates and/or alkalinity in sludge. This process reduces the demand for conditioning chemicals and improves settling or filtering characteristics of the solids.

EMULSION (e-MULL-shun) EMULSION

A liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid held in suspension in the other.

END POINT END POINT

Samples are titrated to the end point. This means that a chemical is added, drop by drop, to a sample until a certain color change (blue to clear, for example) occurs which is called the *END POINT* of the titration. In addition to a color change, an end point may be reached by the formation of a precipitate or the reaching of a specified pH. An end point may be detected by the use of an electronic device such as a pH meter. The completion of a desired chemical reaction.

ENDOGENOUS (en-DODGE-en-us) ENDOGENOUS

A reduced level of respiration (breathing) in which organisms break down compounds within their own cells to produce the oxygen they need.

ENERGY GRADE LINE (EGL) ENERGY GRADE LINE (EGL)

A line that represents the elevation of energy head (in feet) of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel.

ENTERIC ENTERIC

Intestinal.

ENZYMES (EN-zimes) ENZYMES

Enzymes are organic substances which are produced by living organisms and speed up chemical changes.

EQUALIZING BASIN EQUALIZING BASIN

A holding basin in which variations in flow and composition of liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit. Also called a balancing reservoir.

ESTUARIES (ES-chew-wear-eez) ESTUARIES

Bodies of water which are located at the lower end of a river and are subject to tidal fluctuations.

EVAPOTRANSPIRATION (e-VAP-o-trans-spi-RAY-shun) EVAPOTRANSPIRATION

The total water removed from an area by transpiration (plants) and by evaporation from soil, snow and water surfaces.

EXPLOSIMETER EXPLOSIMETER

An instrument used to detect explosive atmospheres. When the **L**ower **E**xplosive **L**imit (L.E.L.) of an atmosphere is exceeded, an alarm signal on the instrument is activated.

F/M RATIO F/M RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\begin{aligned} \frac{\text{Food}}{\text{Microorganisms}} &= \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}} \\ &= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\text{ lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\text{ lbs/gal}} \\ \text{or} \quad &= \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}} \end{aligned}$$

FACULTATIVE (FACK-ul-TAY-tive) FACULTATIVE

Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, facultative bacteria can live under aerobic or anaerobic conditions.

FACULTATIVE POND (FACK-ul-TAY-tive) FACULTATIVE POND

The most common type of pond in current use. The upper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.

FILAMENTOUS BACTERIA (FILL-a-MEN-tuss) FILAMENTOUS BACTERIA

Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.

FILTER AID FILTER AID

A chemical (usually a polymer) added to water to help remove fine colloidal suspended solids.

FIXED FIXED

A sample is "fixed" in the field by adding chemicals that prevent the water quality indicators of interest in the sample from changing before final measurements are performed later in the lab.

FIXED SPRAY NOZZLE FIXED SPRAY NOZZLE

Cone-shaped spray nozzle used to distribute wastewater over the filter media, similar to a lawn sprinkling system. A deflector or steel ball is mounted within the cone to spread the flow of wastewater through the cone, thus causing a spraying action. Also see DISTRIBUTOR.

FLAME POLISHED FLAME POLISHED

Melted by a flame to smooth out irregularities. Sharp or broken edges of glass (such as the end of a glass tube) are rotated in a flame until the edge melts slightly and becomes smooth.

FLIGHTS FLIGHTS

Scraper boards, made from redwood or other rot-resistant woods or plastic, used to collect and move settled sludge or floating scum.

FLOC FLOC

Groups or clumps of bacteria and particles or coagulants and impurities that have come together and formed a cluster. Found in aeration tanks, secondary clarifiers and chemical precipitation processes.

FLOCCULATION (FLOCK-you-LAY-shun) FLOCCULATION

The gathering together of fine particles to form larger particles.

FLOW-EQUALIZATION SYSTEM FLOW-EQUALIZATION SYSTEM

A device or tank designed to hold back or store a portion of peak flows for release during low-flow periods.

FOOD/MICROORGANISM RATIO FOOD/MICROORGANISM RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\begin{aligned} \frac{\text{Food}}{\text{Microorganisms}} &= \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}} \\ &= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\text{ lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\text{ lbs/gal}} \\ \text{or} \quad &= \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}} \end{aligned}$$

Commonly abbreviated F/M Ratio.

FORCE MAIN FORCE MAIN

A pipe that conveys wastewater under pressure from the discharge side of a pump to a point of gravity flow.

FREE AVAILABLE CHLORINE FREE AVAILABLE CHLORINE

The amount of chlorine available in water. This chlorine may be in the form of dissolved gas (Cl_2), hypochlorous acid (HOCl), or hypochlorite ion (OCl^-), but does not include chlorine combined with an amine (ammonia or nitrogen) or other organic compound.

FREE AVAILABLE RESIDUAL CHLORINE FREE AVAILABLE RESIDUAL CHLORINE

That portion of the total residual chlorine remaining in water or wastewater at the end of a specified contact period. Residual chlorine will react chemically and biologically as hypochlorous acid (HOCl) or hypochlorite ion (OCl^-).

FREE CHLORINE FREE CHLORINE

Free chlorine is chlorine (Cl_2) in a liquid or gaseous form. Free chlorine combines with water to form hypochlorous (HOCl) and hydrochloric (HCl) acids. In wastewater free chlorine usually combines with an amine (ammonia or nitrogen) or other organic compounds to form combined chlorine compounds.

FREE OXYGEN FREE OXYGEN

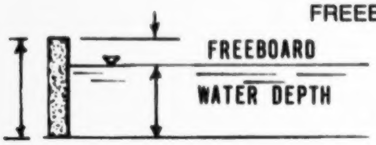
Molecular oxygen available for respiration by organisms. Molecular oxygen is the oxygen molecule, O_2, that is not combined with another element to form a compound.

FREE RESIDUAL CHLORINATION FREE RESIDUAL CHLORINATION

The application of chlorine or chlorine compounds to water or wastewater to produce a free available chlorine residual directly or through the destruction of ammonia (NH_3) or certain organic nitrogenous compounds.

FREEBOARD FREEBOARD

The vertical distance from the normal water surface to the top of the confining wall.



FRICTION LOSS FRICTION LOSS

The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.

GASIFICATION (GAS-i-fi-KAY-shun) GASIFICATION

The conversion of soluble and suspended organic materials into gas during anaerobic decomposition. In clarifiers the resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface. In anaerobic sludge digesters, this gas is collected for fuel or disposed of using the waste gas burner.

GATE GATE

A movable watertight barrier for the control of a liquid in a waterway.

GRAB SAMPLE GRAB SAMPLE

A single sample of wastewater taken at neither a set time nor flow.

GRAVIMETRIC GRAVIMETRIC

A means of measuring unknown concentrations of water quality indicators in a sample by *WEIGHING* a precipitate or residue of the sample.

GRIT GRIT

The heavy mineral material present in wastewater, such as sand, eggshells, gravel, and cinders.

GRIT REMOVAL GRIT REMOVAL

Grit removal is accomplished by providing an enlarged channel or chamber which causes the flow velocity to be reduced and allows the heavier grit to settle to the bottom of the channel where it can be removed.

GROWTH RATE GROWTH RATE

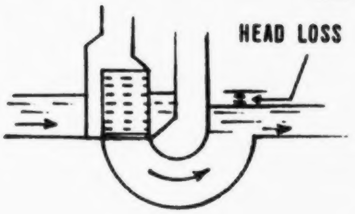
An experimentally determined constant to estimate the unit growth rate of bacteria while degrading organic wastes.

HEAD HEAD

A term used to describe the height or energy of water above a point. A head of water may be measured in either height (feet or meters) or pressure (pounds per square inch or kilograms per square centimeter). Also see DISCHARGE HEAD, DYNAMIC HEAD, STATIC HEAD, SUCTION HEAD, SUCTION LIFT and VELOCITY HEAD.

HEAD LOSS HEAD LOSS

An indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, comminutor, filter or other obstruction. The amount of energy or pressure lost is called "head loss." Head loss is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters.



HEADER HEADER

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "manifold."

HEADWORKS HEADWORKS

The facilities where wastewater enters a wastewater treatment plant. The headworks may consist of bar screens, comminutors, a wet well and pumps.

HEPATITIS HEPATITIS

Hepatitis is an acute viral infection of the liver. Yellow jaundice is one symptom of hepatitis.

HUMUS SLUDGE HUMUS SLUDGE

The sloughed particles of biomass from trickling filter media that are removed from the water being treated in secondary clarifiers.

HYDRAULIC GRADE LINE (HGL) HYDRAULIC GRADE LINE (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. To reduce the release of odors from wastewater, the water surface should be kept as smooth as possible.

HYDRAULIC LOADING HYDRAULIC LOADING

Hydraulic loading refers to the flows (MGD or cu m/day) to a treatment plant or treatment process. Detention times, surface loadings and weir overflow rates are directly influenced by flows.

HYDROGEN ION CONCENTRATION (H^+) HYDROGEN ION CONCENTRATION (H^+)

The weight of hydrogen ion in moles per liter of solution. Commonly expressed as the pH value, which is the logarithm of the reciprocal of the hydrogen-ion concentration.

$$\mathrm{pH} = \log \frac{1}{(H^+)}$$

HYDROGEN SULFIDE (H_2S) HYDROGEN SULFIDE (H_2S)

Hydrogen sulfide is a gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls your sense of smell so that you don't notice it after you have been around it for a while and because the odor is not noticeable in high concentrations. The gas is very poisonous to your respiratory system, explosive, flammable and colorless.

HYDROLOGIC CYCLE (HI-dro-loj-ic) HYDROLOGIC CYCLE

The process of evaporation of water into the air and its return to earth by precipitation (rain or snow). This process also includes transpiration from plants, groundwater movement and runoff into rivers, streams and the ocean.

HYDROLYSIS (hi-DROL-e-sis) HYDROLYSIS

The addition of water to the molecule to break down complex substances into simpler ones.

HYDROSTATIC SYSTEM HYDROSTATIC SYSTEM

In a hydrostatic sludge removal system, the surface of the water in the clarifier is higher than the surface of the water in the sludge well or hopper. This difference in pressure head forces sludge from the bottom of the clarifier to flow through pipes to the sludge well or hopper.

HYGROSCOPIC (HI-grow-SKOP-ic) HYGROSCOPIC

A substance that absorbs or attracts moisture from the air.

HYPOCHLORINATION (hi-po-KLOR-i-NAY-shun) HYPOCHLORINATION

The application of hypochlorite compounds to water or wastewater for the purpose of disinfection.

HYPOCHLORINATORS (hi-poe-KLOR-i-NAY-tors) HYPOCHLORINATORS

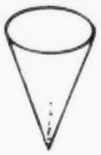
Chlorine pumps or devices used to feed chlorine solutions made from hypochlorites such as bleach (sodium hypochlorite) or calcium hypochlorite.

HYPOCHLORITE (hi-po-KLOR-ite) HYPOCHLORITE

Hypochlorite compounds contain chlorine and are used for disinfection. They are available as liquids or solids (powder, granules, and pellets) in barrels, drums, and cans.

IMHOFF CONE IMHOFF CONE

A clear, cone-shaped container marked with graduations. The cone is used to measure the volume of settleable solids in a specific volume of wastewater.



IMPELLER IMPELLER

A rotating set of vanes designed to impart rotation of a mass of fluid.

IMPELLER PUMP IMPELLER PUMP

Any pump in which the water is moved by the continuous application of power from some rotating mechanical source.

INCINERATION INCINERATION

The conversion of dewatered sludge cake by combustion (burning) to ash, carbon dioxide and water vapor.

INDICATOR (CHEMICAL) INDICATOR (CHEMICAL)

A substance that gives a visible change, usually of color, at a desired point in a chemical reaction, generally at a specified end point.

INDOLE (IN-dole) INDOLE

An organic compound (C_8H_7N) containing nitrogen which has an ammonia odor.

INFILTRATION (IN-fill-TRAY-shun) INFILTRATION

The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.

INFLOW INFLOW

Water discharged into the sewer system from sources other than regular connections. This includes flow from yard drains, foundation drains and around manhole covers. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.

INFLUENT (IN-flu-ent) INFLUENT

Wastewater or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process, or treatment plant.

INHIBITORY SUBSTANCES INHIBITORY SUBSTANCES

Materials that kill or restrict the ability of organisms to treat wastes.

INOCULATE (in-NOCK-you-late) INOCULATE

To introduce a seed culture into a system.

INORGANIC WASTE INORGANIC WASTE

Waste material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Inorganic wastes are chemical substances of mineral origin; whereas organic wastes are chemical substances usually of animal or plant origin. Also see NONVOLATILE MATTER.

INTERFACE INTERFACE

The common boundary layer between two fluids such as a gas (air) and a liquid (water) or a liquid (water) and another liquid (oil).

IONIC CONCENTRATION IONIC CONCENTRATION

The concentration of any ion in solution, generally expressed in moles per liter.

IONIZATION IONIZATION

The process of adding electrons to, or removing electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, and nuclear radiation can cause ionization.

JAR TEST JAR TEST

A laboratory procedure that simulates coagulation/flocculation with differing chemical doses. The purpose of the procedure is to *ESTIMATE* the minimum coagulant dose required to achieve certain water quality goals. Samples of water to be treated are placed in six jars. Various amounts of chemicals are added to each jar, stirred and the settling of solids is observed. The lowest dose of chemicals that provides satisfactory settling is the dose used to treat the water.

JOULE (jewel) JOULE

A measure of energy, work or quantity of heat. One joule is the work done when the point of application of a force of one newton is displaced a distance of one meter in the direction of the force.

KJELDAHL NITROGEN (KELL-doll) KJELDAHL NITROGEN

Organic and ammonia nitrogen.

LAUNDERS (LAWN-ders) LAUNDERS

Sedimentation tank effluent troughs.

LIMIT SWITCH LIMIT SWITCH

A device that regulates or controls the travel distance of a chain or cable.

LINEAL (LIN-e-al) LINEAL

The length in one direction of a line. For example, a board 12 feet long has 12 lineal feet in its length.

LIQUEFACTION (LICK-we-FACK-shun) LIQUEFACTION

The conversion of large solid particles of sludge into very fine particles which either dissolve or remain suspended in wastewater.

LOADING LOADING

Quantity of material applied to a device at one time.

M or MOLAR M or MOLAR

A molar solution consists of one gram molecular weight of a compound dissolved in enough water to make one liter of solution. A gram molecular weight is the molecular weight of a compound in grams. For example, the molecular weight of sulfuric acid (H_2SO_4) is 98. A 1*M* solution of sulfuric acid would consist of 98 grams of H_2SO_4 dissolved in enough distilled water to make one liter of solution.

MBAS MBAS

Methylene **B**lue **A**ctive **S**ubstance. Another name for surfactants, or surface active agents, is methylene blue active substances. The determination of surfactants is accomplished by measuring the color change in a standard solution of methylene blue dye.

MCRT MCRT

Mean **C**ell **R**esidence **T**ime, days. An expression of the average time that a microorganism will spend in the activated sludge process.

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lbs/day}}$$

MLSS MLSS

Mixed **L**iquor **S**uspended **S**olids, mg/*L*. Suspended solids in the mixed liquor of an aeration tank.

MLVSS MLVSS

Mixed **L**iquor **V**olatile **S**uspended **S**olids, mg/*L*. The organic or volatile suspended solids in the mixed liquor of an aeration tank. This volatile portion is used as a measure or indication of the microorganisms present.

MPN (EM-PEA-EN) MPN

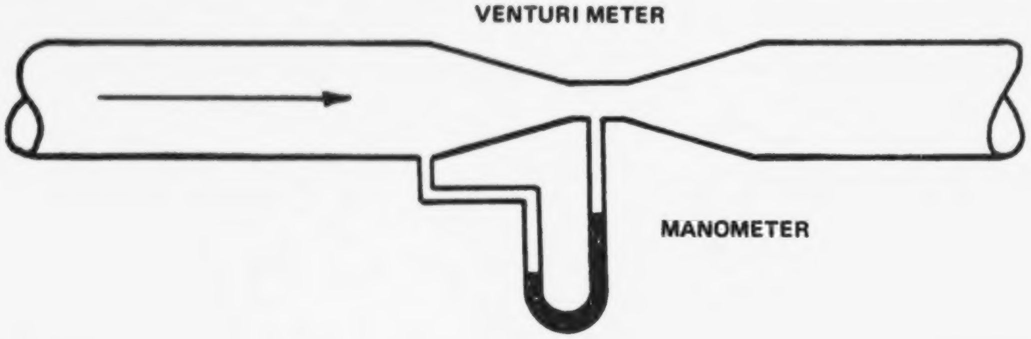
MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume. Expressed as a density or population of organisms per 100 ml.

MANIFOLD MANIFOLD

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "header."

MANOMETER (man-NAH-met-ter) MANOMETER

An instrument for measuring pressure. Usually a glass tube filled with a liquid and used to measure the difference in pressure across a flow-measuring device such as an orifice or Venturi meter. The instrument used to measure blood pressure is a type of manometer.



MASKING AGENTS MASKING AGENTS

Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.

MEAN CELL RESIDENCE TIME (MCRT) MEAN CELL RESIDENCE TIME (MCRT)

An expression of the average time that a microorganism will spend in the activated sludge process.

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lbs/day}}$$

MECHANICAL AERATION MECHANICAL AERATION

The use of machinery to mix air and water so that oxygen can be absorbed into the water. Some examples are: paddle wheels, mixers, or rotating brushes to agitate the surface of an aeration tank; pumps to create fountains; and pumps to discharge water down a series of steps forming falls or cascades.

MEDIA MEDIA

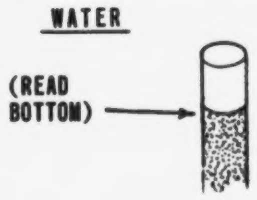
The material in a trickling filter on which slime organisms grow. As settled wastewater trickles over the media, slime organisms remove certain types of wastes thereby partially treating the wastewater. Also the material in a rotating biological contactor or in a gravity or pressure filter.

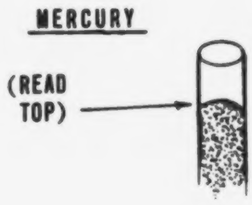
MEDIAN MEDIAN

The middle measurement or value. When several measurements are ranked by magnitude (largest to smallest), half of the measurements will be larger and half will be smaller.

MENISCUS (meh-NIS-cuss) MENISCUS

The curved top of a column of liquid (water, oil, mercury) in a small tube. When the liquid wets the sides of the container (as with water), the curve forms a valley. When the confining sides are not wetted (as with mercury), the curve forms a hill or upward bulge.





MERCAPTANS (mer-CAP-tans) MERCAPTANS

Compounds containing sulfur which have an extremely offensive skunk odor.

MESOPHILIC BACTERIA (mess-O-FILL-lick) MESOPHILIC BACTERIA

Medium temperature bacteria. A group of bacteria that grow and thrive in a moderate temperature range between 68°F (20°C) and 113°F (45°C). The optimum temperature range for these bacteria in anaerobic digestion is 85°F (30°C) to 100°F (38°C).

MICRON (MY-kron) MICRON

A unit of length. One millionth of a meter or one thousandth of a millimeter. One micron equals 0.00004 of an inch.

MICROORGANISMS (micro-ORGAN-is-sums) MICROORGANISMS

Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

MICROSCREEN MICROSCREEN

A device with a fabric straining media with openings usually between 2 and 60 microns. The fabric is wrapped around the outside of a rotating drum. Wastewater enters the open end of the drum and flows out through the rotating screen cloth. At the highest point of the drum, the collected solids are backwashed by high-pressure water jets into a trough located within the drum.

MILLIGRAMS PER LITER, mg/*L* (MILL-i-GRAMS per LEET-er) MILLIGRAMS PER LITER, mg/*L*

A measure of the concentration by weight of a substance per unit volume. For practical purposes, one mg/*L* is equal to one part per million parts (ppm). Thus a liter of water with a specific gravity of 1.0 weighs one million milligrams; and if it contains 10 milligrams of dissolved oxygen, the concentration is 10 milligrams per million milligrams, or 10 milligrams per liter (10 mg/*L*), or 10 parts of oxygen per million parts of water, or 10 parts per million (10 ppm).

MILLIMICRON (MILL-e-MY-cron) MILLIMICRON

One thousandth of a micron or a millionth of a millimeter.

MIXED LIQUOR MIXED LIQUOR

When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank. Mixed liquor also may refer to the contents of mixed aerobic or anaerobic digesters.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS) MIXED LIQUOR SUSPENDED SOLIDS(MLSS)

Suspended solids in the mixed liquor of an aeration tank.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS) MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)

The organic or volatile suspended solids in the mixed liquor of an aeration tank.

MOLECULAR OXYGEN MOLECULAR OXYGEN

The oxygen molecule, O_2, that is not combined with another element to form a compound.

MOLECULAR WEIGHT MOLECULAR WEIGHT

The molecular weight of a compound in grams is the sum of the atomic weights of the elements in the compound. The molecular weight of sulfuric acid (H_2SO_4) in grams is 98.

Element	Atomic Weight	Number of Atoms	Molecular Weight
H	1	2	2
S	32	1	32
O	16	4	64
			98

MOLECULE (MOLL-uh-kule) MOLECULE

A molecule is the smallest portion of an element or compound that still retains or exhibits all the properties of the substance.

MOTILE (MO-till) MOTILE

Motile organisms exhibit or are capable of movement.

MOVING AVERAGE MOVING AVERAGE

To calculate the moving average for the last 7 days, add up the values for the last 7 days and divide by 7. Each day add the most recent day to the sum of values and subtract the oldest value. By using the 7-day moving average, each day of the week is always represented in the calculations.

MUFFLE FURNACE MUFFLE FURNACE

A small oven capable of reaching temperatures up to 600°C. Muffle furnaces are used in laboratories for burning or incinerating samples to determine the amounts of volatile solids and/or fixed solids in samples of wastewater.

MULTI-STAGE PUMP MULTI-STAGE PUMP

A pump that has more than one impeller. A single-stage pump has one impeller.

N or NORMAL N or NORMAL

A normal solution contains one gram equivalent weight of a reactant (compound) per liter of solution. The equivalent weight of an acid is that weight which contains one gram atom of ionizable hydrogen or its chemical equivalent. For example, the equivalent weight of sulfuric acid (H_2SO_4) is 49 (98 divided by 2 because there are two replaceable hydrogen ions). A 1 *N* solution of sulfuric acid would consist of 49 grams of H_2SO_4 dissolved in enough water to make one liter of solution.

NPDES PERMIT NPDES PERMIT

National **P**ollutant **D**ischarge **E**limination **S**ystem permit is the regulatory agency document designed to control all discharges of pollutants from point sources into U.S. waterways. NPDES permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal treatment plants, large agricultural feed lots and return irrigation flows.

NEUTRALIZATION (new-trall-i-ZAY-shun) NEUTRALIZATION

Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.

NITRIFICATION (NYE-tri-fi-KAY-shun) NITRIFICATION

A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

NITRIFYING BACTERIA NITRIFYING BACTERIA

Bacteria that change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).

NITROGENOUS (nye-TROG-en-ous) NITROGENOUS

Nitrogenous compounds contain nitrogen.

NOMOGRAM NOMOGRAM

A chart or diagram containing three or more scales used to solve problems with three or more variables instead of using mathematical formulas.

NONCORRODIBLE NONCORRODIBLE

A material that resists corrosion and will not be eaten away by wastewater or chemicals in wastewater.

NONSPARKING TOOLS NONSPARKING TOOLS

These tools will not produce a spark during use.

NONVOLATILE MATTER NONVOLATILE MATTER

Material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Volatile materials are chemical substances usually of animal or vegetable origin. Also see INORGANIC WASTE.

NUTRIENT CYCLE NUTRIENT CYCLE

The transformation or change of a nutrient from one form to another until the nutrient has returned to the original form, thus completing the cycle. The cycle may take place under either aerobic or anaerobic conditions.

NUTRIENTS NUTRIENTS

Substances which are required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen and phosphorus. Nitrogen and phosphorus are difficult to remove from wastewater by conventional treatment processes because they are water soluble and tend to recycle. Also see NUTRIENT CYCLE.

O & M MANUAL (**O**peration and **M**aintenance Manual) O & M MANUAL

A manual which outlines procedures for operators to follow to operate and maintain a specific wastewater treatment plant and the equipment in the plant.

OSHA OSHA

The Williams-Steiger **O**ccupational **S**afety and **H**ealth **A**ct of 1970 (OSHA) is a law designed to protect the health and safety of industrial workers and treatment plant operators. It regulates the design, construction, operation and maintenance of indusrial plants and wastewater treatment plants. The Act does not apply directly to municipalities at present (1980), *EXCEPT* in those states that have approved plans and have asserted jurisdiction under Section 18 of the OSHA Act. However, wastewater treatment plants have come under stricter regulation in all phases of activity as a result of OSHA standards.

OBLIGATE AEROBES OBLIGATE AEROBES

Bacteria that must have molecular (dissolved) oxygen (DO) to reproduce.

ODOR PANEL ODOR PANEL

A group of people used to measure odors.

OFFSET OFFSET

The difference between the actual value and the desired value (or set point) characteristic of proportional controllers that do not incorporate reset action. Also called DROOP.

OLFACTOMETER (ol-FACT-tom-meter) OLFACTOMETER

A device used to measure odors in the field by diluting odors with odor-free air.

ORGANIC WASTE ORGANIC WASTE

Waste material which comes mainly from animal or plant sources. Organic waste generally can be consumed by bacteria and other small organisms. Inorganic wastes are chemical substances of mineral origin.

ORGANISM ORGANISM

Any form of animal or plant life. Also see BACTERIA.

ORIFICE (OR-uh-fiss) ORIFICE

An opening in a plate, wall or partition. In a trickling filter distributor, the wastewater passes through an orifice to the surface of the filter media. An orifice flange set in a pipe consists of a slot or hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be related to flow in the pipe.

ORTHOTOLIDINE (or-tho-TOL-i-dine) ORTHOTOLIDINE

Orthotolidine is a colorimetric indicator of chlorine residual. If chlorine is present, a yellow-colored compound is produced. This method is no longer approved for tests of effluent chlorine residual.

OVERFLOW RATE OVERFLOW RATE

One of the guidelines for the design of settling tanks and clarifiers in treatment plants.

$$\text{Overflow Rate, gpd/sq ft} = \frac{\text{Flow, gallons/day}}{\text{Surface Area, sq ft}}$$

OXIDATION (ox-i-DAY-shun) OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances. The opposite of REDUCTION.

OXIDATION-REDUCTION POTENTIAL OXIDATION-REDUCTION POTENTIAL

The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant) and used as a qualitative measure of the state of oxidation in wastewater treatment systems.

OXIDIZED ORGANICS OXIDIZED ORGANICS

Organic materials that have been broken down in a biological process. Examples of these materials are carbohydrates and proteins that are broken down to simple sugars.

OXIDIZING AGENT OXIDIZING AGENT

An oxidizing agent is any substance, such as oxygen (O_2) and chlorine (Cl_2), that can add (take on) electrons. When oxygen or chlorine is added to wastewater, organic substances are oxidized. These oxidized organic substances are more stable and less likely to give off odors or to contain disease bacteria. The opposite of REDUCING AGENT.

OZONATION (O-zoe-NAY-shun) OZONATION

The application of ozone to water, wastewater, or air, generally for the purposes of disinfection or odor control.

PACKAGE TREATMENT PLANT PACKAGE TREATMENT PLANT

A small wastewater treatment plant often fabricated at the manufacturer's factory, hauled to the site, and installed as one facility. The package may be either a small primary or a secondary wastewater treatment plant.

PARALLEL OPERATION PARALLEL OPERATION

When wastewater being treated is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit. Also see SERIES OPERATION.

PARASITIC BACTERIA (PAIR-a-SIT-tick) PARASITIC BACTERIA

Parasitic bacteria are those bacteria which normally live off another living organism, known as the "host."

PATHOGENIC ORGANISMS (path-o-JEN-nick) PATHOGENIC ORGANISMS

Bacteria, viruses or cysts which can cause disease (typhoid, cholera, dysentery). There are many types of bacteria which do *NOT* cause disease and which are *NOT* called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.

PERCENT SATURATION PERCENT SATURATION

The amount of a substance that is dissolved in a solution compared with the amount that could be dissolved in the solution, expressed as a percent.

$$\text{Percent Saturation, \%} = \frac{\text{Amount of Sub. that is Dissolved} \times 100\%}{\text{Amount that Could be Dissolved in Solution}}$$

PERCOLATION (PURR-ko-LAY-shun) PERCOLATION

The movement or flow of water through soil or rocks.

PERISTALTIC PUMP (peri-STALL-tick) PERISTALTIC PUMP

A type of positive displacement pump.

pH (PEA-A-ch) pH

pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.

$$pH = \text{Log} \frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is most acid, 14 most basic, and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

PHENOL (FEE-noll) PHENOL

An organic compound that is a derivative of benzene.

PHENOLPHTHALEIN ALKALINITY PHENOLPHTHALEIN ALKALINITY

A measure of the hydroxide ions plus one half of the normal carbonate ions in aqueous suspension. Measured by the amount of sulfuric acid required to bring the water to a pH value of 8.3, as indicated by a change in color of phenolphthalein. It is expressed in milligrams per liter of calcium carbonate.

PHOTOSYNTHESIS (foto-SIN-the-sis) PHOTOSYNTHESIS

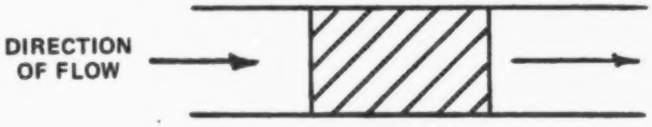
A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. All green plants grow by this process.

PHYSICAL WASTE TREATMENT PROCESS PHYSICAL WASTE TREATMENT PROCESS

Physical waste treatment processes include use of racks, screens, comminutors, and clarifiers (sedimentation and flotation). Chemical or biological reactions are not an important part of a physical treatment process.

PLUG FLOW PLUG FLOW

A type of flow that occurs in tanks, basins or reactors when a slug of wastewater moves through a tank without ever dispersing or mixing with the rest of the wastewater flowing through the tank.



PLUG FLOW

POLLUTION POLLUTION

Any change in the natural state of water which interferes with its beneficial reuse or causes failure to meet water-quality requirements.

POLYELECTROLYTE (POLY-electro-light) POLYELECTROLYTE

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polymer."

POLYMER (POLY-mer) POLYMER

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polymers may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polymers consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polyelectrolyte."

POLYSACCHARIDE (polly-SAC-a-ride) POLYSACCHARIDE

A carbohydrate such as starch, insulin or cellulose.

PONDING PONDING

A condition occurring on trickling filters when the hollow spaces (voids) become plugged to the extent that water passage through the filter is inadequate. Ponding may be the result of excessive slime growths, trash, or media breakdown.

POPULATION EQUIVALENT POPULATION EQUIVALENT

A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pounds of oxygen per day for each person using the system (as measured by the standard BOD test).

$$\text{Pop. Equiv., persons} = \frac{\text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34\text{ lbs/gal}}{0.2\text{ lbs BOD/day/person}}$$

POSTCHLORINATION POSTCHLORINATION

The addition of chlorine to the plant discharge or effluent, *FOLLOWING* plant treatment, for disinfection purposes.

POTABLE WATER (POE-ta-bl) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered safe for domestic consumption.

PRE-AERATION PRE-AERATION

The addition of air at the initial stages of treatment to freshen the wastewater, remove gases, add oxygen, promote flotation of grease, and aid coagulation.

PRECHLORINATION PRECHLORINATION

The addition of chlorine at the headworks of the plant *PRIOR TO* other treatment processes mainly for odor and corrosion control. Also applied to aid disinfection, to reduce plant BOD load, to aid in settling, to control foaming in Imhoff units and to help remove oil.

PRECIPITATE (pre-SIP-i-TATE) PRECIPITATE

To separate (a substance) out in solid form from a solution, as by the use of a reagent. The substance precipitated.

PRECOAT PRECOAT

Application of a free-draining, non-cohesive material such as diatomaceous earth to a filtering media. Precoating reduces the frequency of media washing and facilitates cake discharge.

PRETREATMENT PRETREATMENT

The removal of metal, rocks, rags, sand, eggshells, and similar materials which may hinder the operation of a treatment plant. Pretreatment is accomplished by using equipment such as racks, bar screens, comminutors, and grit removal systems.

PRIMARY TREATMENT PRIMARY TREATMENT

A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

PROCESS VARIABLE PROCESS VARIABLE

A physical or chemical quantity which is usually measured and controlled.

PROTEINACEOUS (PRO-ten-NAY-shus) PROTEINACEOUS

Materials containing proteins which are organic compounds containing nitrogen.

PROTOZOA (pro-toe-ZOE-ah) PROTOZOA

A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.

PRUSSIAN BLUE PRUSSIAN BLUE

A paste or liquid used to show a contact area. Used to determine if gate valve seats fit properly.

PSYCHROPHILIC BACTERIA (sy-kro-FILL-lick) PSYCHROPHILIC BACTERIA

Cold temperature bacteria. A group of bacteria that grow and thrive in temperatures below 68°F (20°C).

PUG MILL PUG MILL

A mechanical device with rotating paddles or blades that is used to mix and blend different materials together.

PURGE PURGE

To remove a gas or vapor from a vessel, reactor or confined space.

PUTREFACTION (PEW-tree-FACK-shun) PUTREFACTION

Biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions.

PUTRESCIBLE (pew-TRES-uh-bull) PUTRESCIBLE

Material that will decompose under anaerobic conditions and produce nuisance odors.

PYROMETER (pie-ROM-uh-ter) PYROMETER

An apparatus used to measure high temperatures.

RAS RAS

Return **A**ctivated **S**ludge, mg/*L*. Settled activated sludge that is collected in the secondary clarifier and returned to the aeration basin to mix with incoming raw or primary settled wastewater.

RABBLING RABBLING

The process of moving or plowing the material inside a furnace by using the center shaft and rabble arms.

RACK RACK

Evenly spaced parallel metal bars or rods located in the influent channel to remove rags, rocks, and cans from wastewater.

RAW WASTEWATER RAW WASTEWATER

Plant influent or wastewater before any treatment.

REAGENT (re-A-gent) REAGENT

A substance which takes part in a chemical reaction and is used to measure, detect, or examine other substances.

RECALCINATION (re-Cal-si-NAY-shun) RECALCINATION

A lime-recovery process in which the calcium carbonate in sludge is converted to lime by heating at 1800°F (980°C).

RECARBONATION (re-CAR-bun-NAY-shun) RECARBONATION

A process in which carbon dioxide is bubbled through the water being treated to lower the pH.

RECEIVING WATER RECEIVING WATER

A stream, river, lake or ocean into which treated or untreated wastewater is discharged.

RECHARGE RATE RECHARGE RATE

Rate at which water is added beneath the ground surface to replenish or recharge groundwater.

RECIRCULATION RECIRCULATION

The return of part of the effluent from a treatment process to the incoming flow.

RECLAMATION RECLAMATION

The operation or process of changing the condition or characteristics of water so that improved uses can be achieved.

RECYCLE RECYCLE

The use of water or wastewater within (internally) a facility before it is discharged to a treatment system. Also see REUSE.

REDUCING AGENT REDUCING AGENT

A reducing agent is any substance, such as the chloride ion (Cl^-) and sulfide ion (S^{-2}), that can give up electrons. The opposite of OXIDIZING AGENT.

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions in wastewater, sulfate compounds or elemental sulfur are reduced to odor-producing hydrogen sulfide (H_2S) or the sulfide ion (S^{-2}). The opposite of OXIDATION.

RELIQUEFACTION (re-LICK-we-FACK-shun) RELIQUEFACTION

The return of a gas to a liquid. For example, a condensation of chlorine gas returning to the liquid form.

REFRACTORY MATERIALS (re-FRACK-tory) REFRACTORY MATERIALS

Material difficult to remove entirely from wastewater such as nutrients, color, taste- and odor-producing substances and some toxic materials.

REPRESENTATIVE SAMPLE REPRESENTATIVE SAMPLE

A portion of material or water identical in content to that in the larger body of material or water being sampled.

RESIDUAL CHLORINE RESIDUAL CHLORINE

Residual chlorine is the amount of chlorine remaining after a given contact time and under specific conditions.

RESPIRATION RESPIRATION

The process in which an organism uses oxygen for its life processes and gives off carbon dioxide.

RETENTION TIME RETENTION TIME

The time water, sludge or solids are retained or held in a clarifier or sedimentation tank. See DETENTION TIME.

RETURN ACTIVATED SLUDGE (RAS) RETURN ACTIVATED SLUDGE (RAS)

Settled activated sludge that is collected in the secondary clarifier and returned to the aeration basin to mix with incoming raw or primary settled wastewater.

REUSE REUSE

The use of water or wastewater after it has been discharged and then withdrawn by another user. Also see RECYCLE.

RIPRAP RIPRAP

Broken stones, boulders, or other materials placed compactly or irregularly on levees or dikes for the protection of earth surfaces against the erosive action of waves.

RISING SLUDGE RISING SLUDGE

Rising sludge occurs in the secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.

ROTAMETER ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or a bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.

ROTARY PUMP ROTARY PUMP

A type of displacement pump consisting essentially of elements rotating in a pump case which they closely fit. The rotation of these elements alternately draws in and discharges the water being pumped. Such pumps act with neither suction nor discharge valves, operate at almost any speed, and do not depend on centrifugal forces to lift the water.

ROTIFERS (ROE-ti-fers) ROTIFERS

Microscopic animals characterized by short hairs on their front end.

ROTOR ROTOR

The rotating part of a machine. The rotor is surrounded by the stationary (non-moving) parts of the machine (stator).

SAR (Sodium Adsorption Ratio) SAR

This ratio expresses the relative activity of sodium ions in the exchange reactions with soil. The ratio is defined as follows:

$$\text{SAR} = \frac{\text{Na}}{\left[\frac{1}{2}(\text{Ca} + \text{Mg})\right]^{1/2}}$$

where Na, Ca, and Mg are concentrations of the respective ions in milliequivalents per liter of water.

$$\text{Na, meq}/L = \frac{\text{Na, mg}/L}{23.0\ \text{mg/meq}} \qquad \text{Ca, meq}/L = \frac{\text{Ca, mg}/L}{20.0\ \text{mg/meq}}$$

$$\text{Mg, meq}/L = \frac{\text{Mg, mg}/L}{12.15\ \text{mg/meq}}$$

SCFM SCFM

Cubic Feet of air per Minute at Standard conditions of temperature, pressure and humidity.

SVI (Sludge Volume Index)	SVI

This is a test used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared with its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.

$$\text{SVI} = \frac{\text{Wet Settled Sludge, ml} \times 1000}{\text{Dried Sludge Solids, mg}}$$

SANITARY SEWER (SAN-eh-tare-ee SUE-er) SANITARY SEWER

A sewer intended to carry wastewater from homes, businesses, and industries. Storm water runoff should be collected and transported in a separate system of pipes.

SAPROPHYTIC ORGANISMS (SAP-pro-FIT-tik) SAPROPHYTIC ORGANISMS

Organisms living on dead or decaying organic matter. They help natural decomposition of the organic solids in wastewater.

SCREEN SCREEN

A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.

SEALING WATER SEALING WATER

Water used to prevent wastewater or dirt from reaching moving parts. Sealing water is at a higher pressure than the wastewater it is keeping out of a mechanical device.

SECCHI DISC (SECK-key) SECCHI DISC

A flat, white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded secchi disc reading.

SECONDARY TREATMENT SECONDARY TREATMENT

A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

SEED SLUDGE SEED SLUDGE

In wastewater treatment, seed, seed culture or seed sludge refers to a mass of sludge which contains very concentrated populations of microorganisms. When a seed sludge is mixed with the wastewater or sludge being treated, the process of biological decomposition takes place more rapidly.

SEIZING SEIZING

Seizing occurs when an engine overheats and a component expands to the point where the engine will not run. Also called "freezing."

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SEPTICITY (sep-TIS-it-tee) SEPTICITY

Septicity is the condition in which organic matter decomposes to form foul-smelling products associated with the absence of free oxygen. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SERIES OPERATION SERIES OPERATION

When wastewater being treated flows through one treatment unit and then flows through another similar treatment unit. Also see PARALLEL OPERATION.

SET POINT SET POINT

The position at which the control or controller is set. This is the same as the desired value of the process variable.

SEWAGE SEWAGE

The used water and solids from homes that flow to a treatment plant. The preferred term is wastewater.

SHEAR PIN SHEAR PIN

A straight pin with a groove around the middle that will weaken the pin and cause it to fail when a certain load or stress is exceeded. The purpose of the pin is to protect equipment from damage due to excessive loads or stresses.

SHOCK LOAD SHOCK LOAD

The arrival at a plant of a waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and sloughing off of the growth or slime on the trickling-filter media. Organic or hydraulic overloads also can cause a shock load.

SHORT-CIRCUITING SHORT-CIRCUITING

A condition that occurs in tanks or ponds when some of the water or wastewater travels faster than the rest of the flowing water.

SHREDDING SHREDDING

Comminution. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment. *SHREDDING* and *COMMINUTION* usually mean the same thing.

SIDESTREAM SIDESTREAM

Wastewater flows that develop from other storage or treatment facilities. This wastewater may or may not need additional treatment.

SIGNIFICANT FIGURE SIGNIFICANT FIGURE

The number of accurate numbers in a measurement. If the distance between two points is measured to the nearest hundredth and recorded as 238.41 feet, the measurement has five significant figures.

SINGLE-STAGE PUMP SINGLE-STAGE PUMP

A pump that has only one impeller. A multi-stage pump has more than one impeller.

SKATOLE (SKATE-tole) SKATOLE

An organic compound (C_9H_9N) containing nitrogen which has a fecal odor.

SLAKE SLAKE

To become mixed with water so that a true chemical reaction takes place, such as in the slaking of lime.

SLOUGHINGS (SLUFF-ings) SLOUGHINGS

Trickling-filter slimes that have been washed off the filter media. They are generally quite high in BOD and will lower effluent quality unless removed.

SLUDGE (sluj) SLUDGE

The settleable solids separated from liquids during processing or the deposits of foreign materials on the bottoms of streams or other bodies of water.

SLUDGE AGE SLUDGE AGE

A measure of the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process.

$$\text{Sludge Age, days} = \frac{\text{Suspended Solids Under Aeration, lbs or kg}}{\text{Suspended Solids Added, lbs/day or kg/day}}$$

SLUDGE DENSITY INDEX (SDI) SLUDGE DENSITY INDEX (SDI)

This test is used in a way similar to the Sludge Volume Index (SVI) to indicate the settleability of a sludge in a secondary clarifier or effluent. SDI = 100/SVI. Also see SLUDGE VOLUME INDEX (SVI).

SLUDGE DIGESTION SLUDGE DIGESTION

The process of changing organic matter in sludge into a gas or a liquid or a more stable solid form. These changes take place as microorganisms feed on sludge in anaerobic (more common) or aerobic digesters.

SLUDGE GASIFICATION SLUDGE GASIFICATION

A process in which soluble and suspended organic matter are converted into gas by anaerobic decomposition. The resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface.

SLUDGE VOLUME INDEX (SVI)

SLUDGE VOLUME INDEX (SVI)

This is a test used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared with its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.

$$\text{SVI} = \frac{\text{Wet Settled Sludge, ml} \times 1000}{\text{Dried Sludge Solids, mg}}$$

SLUDGE-VOLUME RATIO (SVR)

SLUDGE-VOLUME RATIO (SVR)

The volume of sludge blanket divided by the daily volume of sludge pumped from the thickener.

SLUGS

SLUGS

Intermittent releases or discharges of industrial wastes.

SLURRY (SLUR-e)

SLURRY

A thin watery mud or any substance resembling it (such as a grit slurry or a lime slurry).

SODIUM ADSORPTION RATIO (SAR)

SODIUM ABSORPTION RATIO (SAR)

This ratio expresses the relative activity of sodium ions in the exchange reactions with soil. The ratio is defined as follows:

$$\text{SAR} = \frac{\text{Na}}{[\tfrac{1}{2}\,(\text{Ca} + \text{Mg})]^{1/2}}$$

where Na, Ca, and Mg are concentrations of the respective ions in milliequivalents per liter of water.

$$\text{Na, meq}/L = \frac{\text{Na, mg}/L}{23.0\text{ mg/meq}} \qquad \text{Ca, meq}/L = \frac{\text{Ca, mg}/L}{20.0\text{ mg/meq}}$$

$$\text{Mg, meq}/L = \frac{\text{Mg, mg}/L}{12.15\text{ mg/meq}}$$

SOFTWARE PROGRAMS

SOFTWARE PROGRAMS

Computer programs designed and written to monitor and control wastewater treatment processes or other processes.

SOLUBLE BOD

SOLUBLE BOD

Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.

SOLUTE

SOLUTE

The substance dissolved in a solution. A solution is made up of the solvent and the solute.

SOLUTION

SOLUTION

A liquid mixture of dissolved substances. In a solution it is impossible to see all the separate parts.

SPECIFIC GRAVITY

SPECIFIC GRAVITY

Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles usually have a specific gravity of 0.5 to 2.5.

SPLASH PAD

SPLASH PAD

A structure made of concrete or other durable material to protect bare soil from erosion by splashing or falling water.

STABILIZE

STABILIZE

To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.

STABILIZED WASTE

STABILIZED WASTE

A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

STANDARD SOLUTION

STANDARD SOLUTION

A solution in which the exact concentration of a chemical or compound is known.

STANDARDIZE STANDARDIZE

(1) To compare with a standard. In wet chemistry, to find out the exact strength of a solution by comparing with a standard of known strength. This information is used to adjust the strength by adding more water or more of the substance dissolved. (2) To compare an instrument or device with a standard. This helps you to adjust the instrument so that it reads accurately or to prepare a scale, graph or chart that is accurate.

STASIS (STAY-sis) STASIS

Stagnation or inactivity of the life processes within organisms.

STATIC HEAD STATIC HEAD

When water is not moving, the distance (in feet or meters) from a point to the water surface.

STATOR STATOR

That portion of a machine which contains the stationary (non-moving) parts that surround the moving parts.

STEP-FEED AERATION STEP-FEED AERATION

Step-feed aeration is a modification of the conventional activated sludge process. In step aeration, primary effluent enters the aeration tank at several points along the length of the tank, rather than all of the primary effluent entering at the beginning or head of the tank and flowing through the entire tank.

STERILIZATION (star-uh-luh-ZAY-shun) STERILIZATION

The removal or destruction of all living microorganisms, including pathogenic and saprophytic bacteria, vegetative forms and spores. Compare with DISINFECTION.

STETHOSCOPE STETHOSCOPE

An instrument used to magnify sounds and convey them to the ear.

STOP LOG STOP LOG

A log or board in an outlet box or device used to control the water level in ponds.

STORM SEWER STORM SEWER

A separate sewer that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes.

STRIPPED GASES STRIPPED GASES

Gases that are released from a liquid by bubbling air through the liquid or by allowing the liquid to be sprayed or tumbled over media.

STRIPPED ODORS STRIPPED ODORS

Odors that are released from a liquid by bubbling air through the liquid or by allowing the liquid to be sprayed and/or tumbled over media.

STUCK STUCK

Not working. A stuck digester does not decompose organic matter properly. The digester is characterized by low gas production, high volatile acid to alkalinity relationship, and poor liquid-solids separation. A digester in a stuck condition is sometimes called a "sour" or "upset" digester.

SUCTION HEAD SUCTION HEAD

The *POSITIVE* pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the suction side of a pump. The pressure can be measured from the center line of the pump *UP TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUCTION LIFT SUCTION LIFT

The *NEGATIVE* pressure (in feet (meters) or inches (centimeters) of mercury vacuum) on the suction side of the pump. The pressure can be measured from the center line of the pump *DOWN TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUPERNATANT (sue-per-NAY-tent) SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.

SURFACE LOADING	SURFACE LOADING

Surface loading is calculated by dividing the flow into a sedimentation tank or a clarifier by the surface area of the unit.

$$\text{Surface Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

SURFACTANT	SURFACTANT

Abbreviation for surface-active agent. The active agent in detergents that possesses a high cleaning ability.

SUSPENDED SOLIDS	SUSPENDED SOLIDS

(1) Solids that either float on the surface or are suspended in water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in *STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER* and referred to as "Total Suspended Solids Dried at 103-105°C."

TOC	TOC

Total Organic Carbon. TOC measures the amount of organic carbon in water.

TARE WEIGHT	TARE WEIGHT

The weight of an empty weighing dish or container.

TERTIARY TREATMENT (TER-she-AIR-ee)	TERTIARY TREATMENT

Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration. Also called ADVANCED WASTE TREATMENT.

THERMOPHILIC BACTERIA (thermo-FILL-lick)	THERMOPHILIC BACTERIA

Hot temperature bacteria. A group of bacteria that grow and thrive in temperatures above 113°F (45°C). The optimum temperature range for these bacteria in anaerobic decomposition is 120°F (49°C) to 135°F (57°C).

THIEF HOLE	THIEF HOLE

A digester sampling well.

THRESHOLD ODOR	THRESHOLD ODOR

The minimum odor of a sample (gas or water) that can just be detected after successive odorless (gas or water) dilutions.

TIME LAG	TIME LAG

The time required for processes and control systems to respond to a signal or to reach a desired level.

TITRATE (TIE-trate)	TITRATE

To *TITRATE* a sample, a chemical solution of known strength is added on a drop-by-drop basis until a color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical solution to completion of the reaction as signaled by the end point.

TOTAL DYNAMIC HEAD (TDH)	TOTAL DYNAMIC HEAD (TDH)

When a pump is lifting or pumping water, the vertical distance (in feet or meters) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TOTAL RESIDUAL CHLORINE	TOTAL RESIDUAL CHLORINE

The amount of chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine. Also see RESIDUAL CHLORINE.

TOTALIZER	TOTALIZER

A device that continuously sums or adds the flow into a plant in gallons or million gallons or some other unit of measurement.

TOXIC (TOX-ick)	TOXIC

Poisonous.

TOXICITY (tox-IS-it-tee)	TOXICITY

A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

TRANSPIRATION (TRAN-spear-RAY-shun)	TRANSPIRATION

The process by which water vapor is lost to the atmosphere from living plants.

TRICKLING FILTER TRICKLING FILTER

A treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water treated.

TRICKLING-FILTER MEDIA TRICKLING-FILTER MEDIA

Rocks or other durable materials that make up the body of the filter. Synthetic (manufactured) media have been used successfully.

TRUNK SEWER TRUNK SEWER

A sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population.

TURBID TURBID

Having a cloudy or muddy appearance.

TURBIDIMETER TURBIDIMETER

See TURBIDITY METER.

TURBIDITY (ter-BID-it-tee) TURBIDITY

The cloudy appearance of water caused by the presence of suspended and colloidal matter. In the waterworks field, a turbidity measurement is used to indicate the clarity of water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended particles. Turbidity cannot be directly equated to suspended solids because white particles reflect more light than dark-colored particles and many small particles will reflect more light than an equivalent large particle.

TURBIDITY METER TURBIDITY METER

An instrument for measuring and comparing the turbidity of liquids by passing light through them and determining how much light is reflected by the particles in the liquid.

TURBIDITY UNITS (TU) TURBIDITY UNITS (TU)

Turbidity units are a measure of the cloudiness of water. If measured by a nephelometric (deflected light) instrumental procedure, turbidity units are expressed in nephelometric turbidity units (NTU) or simply TU. Those turbidity units obtained by visual methods are expressed in Jackson Turbidity Units (JTU) which are a measure of the cloudiness of water, they are used to indicate the clarity of water. There is no real connection between NTUs and JTUs. The Jackson turbidimeter is a visual method and the nephelometer is an instrumental method based on deflected light.

TWO-STAGE FILTERS TWO-STAGE FILTERS

Two filters are used. Effluent from the first filter goes to the second filter, either directly or after passing through a clarifier.

ULTRAFILTRATION ULTRAFILTRATION

A membrane filter process used for the removal of organic compounds in an aqueous (watery) solution.

UPSET UPSET

An upset digester does not decompose organic matter properly. The digester is characterized by low gas production, high volatile acid/alkalinity relationship, and poor liquid-solids separation. A digester in an upset condition is sometimes called a "sour" or "stuck" digester.

VECTOR VECTOR

An insect or other organism capable of transmitting germs or other agents of disease.

VELOCITY HEAD VELOCITY HEAD

A vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

VOLATILE (VOL-a-til) VOLATILE

A volatile substance is one that is capable of being evaporated or changed to a vapor at relatively low temperatures.

VOLATILE ACIDS VOLATILE ACIDS

Acids produced during digestion. Fatty acids which are soluble in water and can be steam-distilled at atmospheric pressure. Also called "organic acids." Volatile acids are commonly reported as equivalent to acetic acid.

VOLATILE LIQUIDS VOLATILE LIQUIDS

Liquids which easily vaporize or evaporate at room temperature.

VOLATILE SOLIDS VOLATILE SOLIDS

Those solids in water, wastewater, or other liquids that are lost on ignition of the dry solids at 550°C.

VOLUMETRIC VOLUMETRIC

A means of measuring unknown concentrations of water quality indicators in a sample *BY DETERMINING THE VOLUME* of titrant or liquid reagent needed to complete particular reactions.

VOLUTE (vol-LOOT) VOLUTE

The spiral-shaped casing which surrounds a pump, blower, or turbine impeller and collects the liquid or gas discharged by the impeller.

WAS WAS

Waste Activated Sludge, mg/*L*. The excess growth of microorganisms which must be removed from the process to keep the biological system in balance.

WASTE ACTIVATED SLUDGE (WAS) WASTE ACTIVATED SLUDGE (WAS)

The excess growth of microorganisms which must be removed from the process to keep the biological system in balance.

WASTEWATER WASTEWATER

The used water and solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WATER HAMMER WATER HAMMER

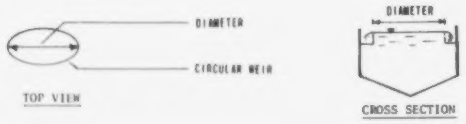
The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.

WEIR (weer) WEIR

(1) A wall or plate placed in an open channel and used to measure the flow. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

WEIR DIAMETER (weer) WEIR DIAMETER

Many circular clarifiers have a circular weir within the outside edge of the clarifier. All the water leaving the clarifier flows over this weir. The diameter of the weir is the length of a line from one edge of a weir to the opposite edge and passing through the center of the circle formed by the weir.



WEIR, PROPORTIONAL (weer) WEIR, PROPORTIONAL

A specially shaped weir in which the flow through the weir is directly proportional to the head.

WET OXIDATION WET OXIDATION

A method of treating or conditioning sludge before the water is removed. Compressed air is blown into the liquid sludge. The air and sludge mixture is fed into a pressure vessel where the organic material is stabilized. The stabilized organic material and inert (inorganic) solids are then separated from the pressure vessel effluent by dewatering in lagoons or by mechanical means.

WET WELL WET WELL

A compartment or room in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

Y, GROWTH RATE Y, GROWTH RATE

An experimentally determined constant to estimate the unit growth rate of bacteria while degrading organic wastes.

ZOOGLEAL FILM (ZOE-glee-al) ZOOGLEAL FILM

A complex population of organisms that form a "slime growth" on the trickling-filter media and break down the organic matter in wastewater. These slimes consist of living organisms feeding on the wastes in wastewater, dead organisms, silt, and other debris. "Slime growth" is a more common word.

ZOOGLEAL MASS (ZOE-glee-al) ZOOGLEAL MASS

Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes. These masses may be formed for or function as the protection against predators and for storage of food supplies. Also see BIOMASS.

SUBJECT INDEX

INDUSTRIAL WASTE TREATMENT

NOTE: All chapter numbers refer to Volumes I and II of **OPERATION OF WASTEWATER TREATMENT PLANTS.**

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